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INVESTIGATION OF FLYING QUALITIES OF MILITARY AIRCRAFT AT HIGH ANGLES OF ATTACK. VOLUME II. APPENDICES

Donald E. Johnston, et al

Systems Technology, Incorporated

Prepared for:

Air Force Flight Dynamics Laboratory

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INVESTIGATION OF FLYING QUALITIES OF MILITARY AIRCRAFT AT HIGH ANGLES OF ATTACK
Volume II. Appendices

SYSTEMS TECHNOLOGY, INC.
HAWTHORNE, CALIFORNIA

JUNE 1974

TECHNICAL REPORT AFFDL-TR-74-61

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AIR FORCE FLIGHT DYNAMICS LABORATORY
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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FOR THE COMMANDER:

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An investigation of handling qualities in stall-departure flight regimes has been conducted. The study involved key parameter identification, systems analysis and piloted simulation. The technical results and conclusions are detailed in Vol. I. This second volume contains support data in the form of appendices. These include equations of motion and the A-7 high angle of attack aerodynamic data used in the nonlinear six-degree-of-freedom digital simulation. It also contains stability derivatives and transfer functions evaluated at specific flight

(Continued on back)

20. Abstract (Continued)

conditions near stall. The five-degree-of-freedom piloted simulation (analog) is described in detail. Time traces of motion responses to step control surface inputs are presented for the nine dynamic configurations employed in this simulation. The pilot commentary recorded during the simulation is also included.

FOREWORD

This research program was sponsored by the Air Force Flight Dynamics Laboratory, Air Force Systems Command, under Contract F33615-73-C-3101, Project 1917, Task 191700. The project monitor was Mr. David R. Mayhew, AFFDL/FGC. The STI technical director was Mr. I. L. Ashkenas. Mr. D. E. Johnston was principal investigator and STI project engineer. Mr. J. R. Hogge was responsible for all analog simulation. All analytic work was performed at STI, Hawthorne, California. The piloted simulation was accomplished on the fighter simulator facility of the Lear Siegler, Inc., Astronics Division, Santa Monica, California.

The authors wish to express acknowledgment and thanks to their many coworkers for contributions, both general and detailed, in the program: at STI, Mr. G. L. Teper for invaluable aid in finding the "bugs" in the digital programs and Mr. R. E. Magdaleno for assistance in the describing function data analysis; at LSI, Messrs. Geert Gevaert and J. R. Flynn for assistance in the setup and operation of the simulator facility. Special thanks are due to Major M. V. Love, 6512 Test Squadron, and Major J. P. Schoeppner, Jr., USAF Test Pilot School, Edwards Air Force Base, for their helpful suggestions in the simulation checkout and their willing and cheerful performance of the sometimes tedious simulation experiments.

Finally, appreciation is extended to Messrs. D. R. Mayhew, R. J. Woodcock, and D. K. Bowser of AFFDL/FGC; Mr. R. G. Hoey, AFFTC/FTT; Mr. J. R. Chambers, of NASA Langley; and M. E. Shields of Vought Systems Division, LTV, for their support in obtaining much of the aero data and various technical discussions.

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APPENDIX I

EQUATIONS OF MOTION

This appendix summarizes the nonlinear six degrees of freedom equations of motion for the aircraft which were used in the digital simulation. The equations are consistent with the following assumptions.

A. ASSUMPTIONS

1. The airframe is assumed to be a rigid body.
2. The earth is assumed to be fixed in inertial space.
3. The mass and mass distribution of the vehicle are assumed to be constant.
4. The aircraft has a plane of symmetry.
5. Effects associated with rotation of the vertical relative to inertial space are assumed negligible; the magnitude of the gravity vector is assumed constant.

B. AXIS SYSTEMS

All the axis systems (see Fig. 1) have their origin at the aircraft center of gravity (c.g.). The Earth Axis system is oriented with the Z_E axis along the local gravity vector and the X_E, Y_E axes in a horizontal plane with arbitrary, but fixed, direction.

The Body Axes are fixed in the aircraft with the X_B axis positive forward along the fuselage reference line. The Z_B axis is in the plane of symmetry, positive down, and the Y_B axis is perpendicular to the plane of symmetry, positive out the right wing. The Body Axes are located relative to the Earth Axes by conventional Euler Angles, Ψ, Θ, and Φ. Ψ is a rotation of the Body Axes from the Earth Axes about the Z_E axis; Θ is a rotation about the intermediate Y_B axis; and, finally, Φ is about the X_B axis. All angles and angular rates are positive in a righthanded sense.

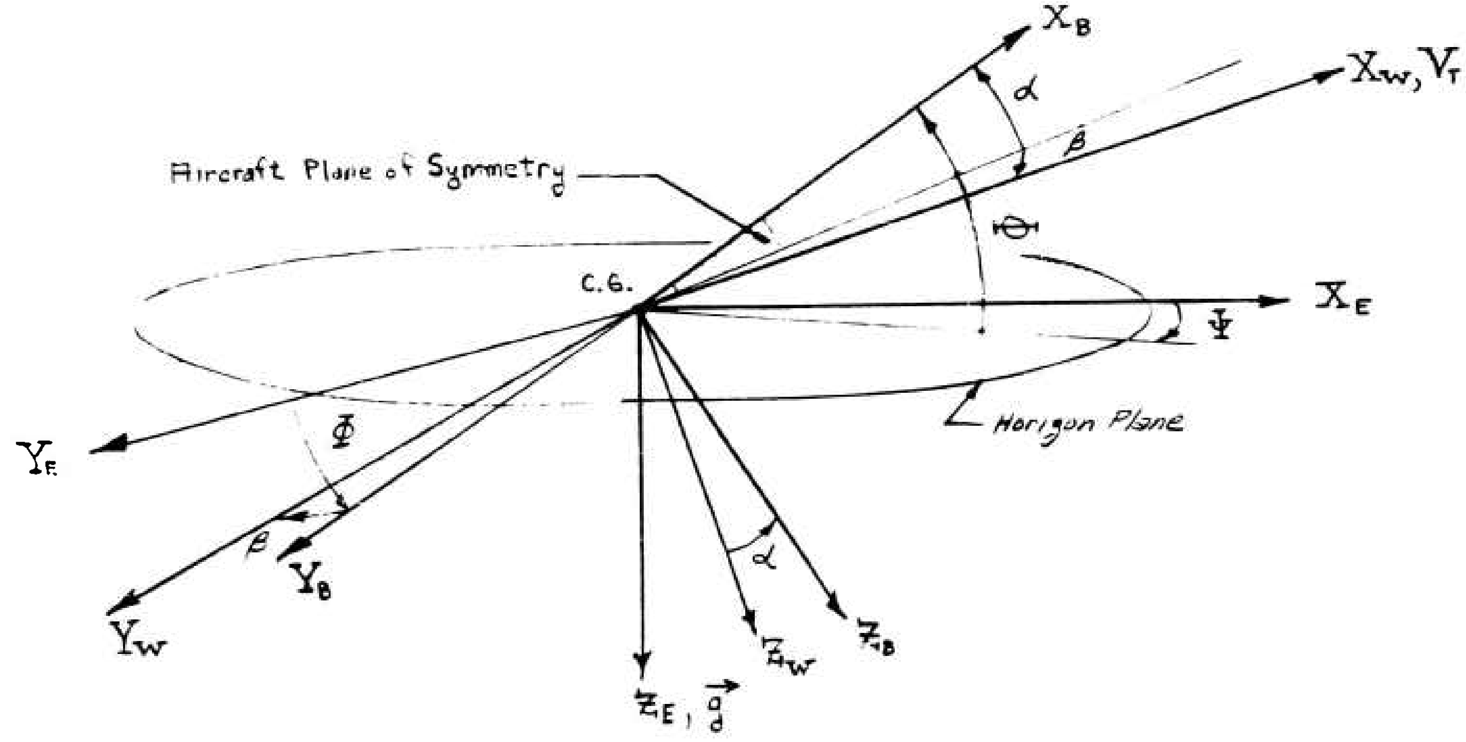


Figure 1. Axis Systems

The final axis system is called Flight Path Axes. They are aligned with the aircraft inertial velocity. For the still-air case considered here they are identical to Wind Axes (usually aligned with the aircraft velocity relative to the air mass). Herein we use the more conventional W subscript and Flight and Wind interchangeably. The $\mathbf{X_W}$ axis lies along the aircraft total velocity vector, V_T; the Z_W axis is in the aircraft plane of symmetry; and the $\mathbf{Y_W}$ axis completes the righthanded orthogonal set. The Wind or Flight Axes are located relative to the body by the angles of attack, α, and side slip, β (α is a rotation about the $\mathbf{Y_B}$ axis; β about the $\mathbf{Z_W}$ axis).

C. MOMENT EQUATIONS

The rate of change with respect to time of the components of the aircraft angular velocity is related to the applied moments about the c.g. by:

$$\dot{P} = (c_1 R + c_2 P)Q + c_3 \mathcal{L} + c_4 N$$

$$\dot{Q} = c_5 RP + c_6 (R^2 - P^2) + c_7 M$$

$$\dot{R} = (c_8 P + c_9 R)Q + c_4 \mathcal{L} + c_{10} N$$

$$c_1 = G\left\{(I_y - I_z)I_z - I_{xz}^2\right\} \qquad c_6 = I_{xz}/I_y$$

$$c_2 = G\left\{I_x - I_y + I_z\right\}I_{xz} \qquad c_7 = 1./I_y$$

$$c_3 = G\,I_z \qquad c_8 = G\left\{(I_x - I_y)I_x + I_{xz}^2\right\}$$

$$c_4 = G\,I_{xz} \qquad c_9 = G\left\{I_y - I_z - I_x\right\}I_{xz}$$

$$c_5 = (I_z - I_x)/I_y \qquad c_{10} = G\,I_x$$

$$G = 1/(I_x I_z - I_{xz}^2)$$

P, Q, and R are the instantaneous projections of the aircraft total angular velocity vector on the $\mathbf{X_B}$, $\mathbf{Y_B}$, $\mathbf{Z_B}$ axes. I_x, I_y, I_z, and I_{xz} are the moments and product of inertia with respect to these axes. $\mathcal{L}$, M, and N are moments about the Body Axes due to aerodynamics and aircraft thrust.

D. FORCE EQUATIONS

The rates of change of α, β, and the aircraft total translational velocity, V_T, are related to the external forces by:

$$\dot{\alpha} = Q - \tan\beta(P\cos\alpha + R\sin\alpha) + Z_W/(mV_T\cos\beta)$$

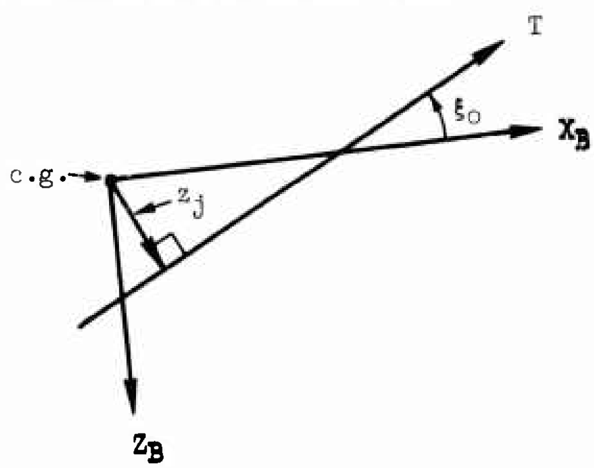
$$\dot{\beta} = P\sin\alpha - R\cos\alpha + Y_W/(mV_T)$$

$$\dot{V}_T = X_W/m$$

X_W, Y_W, and Z_W are the components of the total external forces (aerodynamic, thrust, and gravity) along the Flight Path Axes. m is the aircraft mass

E. THRUST GEOMETRY

The thrust is assumed to lie in the aircraft plane of symmetry and is oriented with respect to the Body Axes by the thrust inclination, ξ_o, and offset, z_j, as indicated in the sketch below.



F. BODY AXIS MOMENTS

The roll, $\mathcal{L}$, and yaw, N, moments are due to aerodynamics only, while the pitching moment, M, includes a thrust term. These are given by:

$$\mathcal{L} = \bar{q}SbC_\ell$$

$$M = \bar{q}ScC_m + z_jT$$

$$N = \bar{q}SbC_n$$

$\bar{q}$ is the dynamic pressure; b, c, and S are the reference span, chord, and wing area, respectively. C_ℓ, C_m, and C_n are the total body-axis non-dimensional aerodynamic moment coefficients* (referenced to the c.g.).

G. FLIGHT PATH AXIS FORCES

The forces along the Flight Path Axes have components due to thrust, T, weight, mg, and aerodynamics. They are given by:

$$
\begin{aligned}
X_W &= T \cos\beta \cos(\alpha + \xi_o) \\
&\quad + mg\left\{\cos\Theta \cos\Phi \sin\alpha \sin\beta - \sin\Theta \cos\alpha \cos\beta + \cos\Theta \sin\Phi \sin\beta\right\} \\
&\quad + Y_A \sin\beta - D \cos\beta
\end{aligned}
$$

$$
\begin{aligned}
Y_W &= -T \sin\beta \cos(\alpha + \xi_o) \\
&\quad + mg\left\{\cos\Theta \sin\Phi \cos\beta + \sin\Theta \cos\alpha \sin\beta - \cos\Theta \cos\Phi \sin\alpha \sin\beta\right\} \\
&\quad + Y_A \cos\beta + D \sin\beta
\end{aligned}
$$

$$
\begin{aligned}
Z_W &= -T \sin(\alpha + \xi_o) + mg\left\{\sin\Theta \sin\alpha + \cos\Theta \cos\Phi \cos\alpha\right\} \\
&\quad - L
\end{aligned}
$$

L, D, and Y_A are the aerodynamic forces and are given by:

$$
\begin{aligned}
L &= \bar{q}SC_L \\
D &= \bar{q}SC_D \\
Y_A &= \bar{q}SC_y
\end{aligned}
$$

C_L, C_D, and C_y are the lift, drag, and side force coefficients.* Lift, L, and drag, D, are assumed in the plane of symmetry; lift positive up and perpendicular to the velocity vector, drag positive aft and along the projection of the total velocity in the plane of symmetry. The side force, Y_A, is

*See Appendix II.

that component of the total aerodynamic force which is perpendicular to the plane of symmetry; it lies along the Y_B axis and is positive out the right wing.

H. EULER ANGLE RATES

The Euler angle rates are related to the angular velocity components by:

$$\dot{\Psi} = (R \cos \Phi + Q \sin \Phi)/\cos \Theta$$

$$\dot{\Theta} = Q \cos \Phi - R \sin \Phi$$

$$\dot{\Phi} = P + \dot{\Psi} \sin \Theta$$

I. BODY AXIS VELOCITIES

The components of the total velocity along the Body Axes are:

$$U = V_T \cos \alpha \cos \beta$$

$$V = V_T \sin \beta$$

$$W = V_T \sin \alpha \cos \beta$$

J. EARTH AXIS VELOCITIES

The body axis velocities are translated through the Euler angles to yield the earth axis velocities.

$$\dot{X} = U \cos \Theta \cos \Psi + W(\cos \Phi \sin \Theta \cos \Psi + \sin \Phi \sin \Psi) + V(\sin \Phi \sin \Theta \cos \Psi - \cos \Phi \sin \Psi)$$

$$\dot{Y} = U \cos \Theta \sin \Psi + V(\sin \Phi \sin \Theta \sin \Psi + \cos \Phi \cos \Psi) + W(\cos \Phi \sin \Theta \sin \Psi - \sin \Phi \cos \Psi)$$

$$\dot{Z} = -U \sin \Theta + V \sin \Phi \cos \Theta + W \cos \Phi \cos \Theta$$

The rate of change of altitude is then given by:

$$\dot{H} = -\dot{Z}$$

APPENDIX II

A-7 HIGH-ANGLE-OF-ATTACK AERODYNAMIC DATA

This appendix contains the nonlinear, digitized, aerodynamic coefficients used in this study program. The equations for the total nondimensional aerodynamic moment and force coefficients are presented first. These are followed by the digital tables and plots of selected coefficients.

A. BODY AXIS MOMENT COEFFICIENTS

The total aerodynamic moment coefficients are:

$$C_\ell = C_\ell(\delta_e,\alpha,\beta) + C_\ell(\alpha,\delta_{a_{Right}}) - C_\ell(\alpha,\delta_{a_{Left}})$$

$$+ \mathrm{sgn}_{\delta_a} C_\ell(\alpha,\delta_s) + C_{\ell_{\delta_r}}(\alpha)\delta_r + (b/2V)[C_{\ell_p}(\alpha)p + C_{\ell_r}(\alpha)r]$$

$$C_m = C_m(\alpha,\delta_e) + C_m(\alpha,\delta_{a_{Right}}) + C_m(\alpha,\delta_{a_{Left}})$$

$$+ C_m(\alpha,\delta_s) + (c/2V)[C_{m_q}(\alpha,\delta_e)q + C_{m_{\dot\alpha}}(\alpha,\delta_e)\dot\alpha]$$

$$- (x_{CG}/qS)[L \cos \alpha + D \sin \alpha]$$

$$C_n = C_n(\delta_e,\alpha,\beta) + C_n(\alpha,\delta_{a_{Right}}) - C_n(\alpha,\delta_{a_{Left}})$$

$$+ \mathrm{sgn}_{\delta_a} C_n(\alpha,\delta_s) + C_{n_{\delta_r}}(\alpha)\,\delta_r + (b/2V)[C_{n_p}(\alpha)p + C_{n_r}(\alpha)\,r] - (x_{CG}Y_A/qS)$$

B. FORCE COEFFICIENTS

The total aerodynamic force coefficients are:

$$C_L = C_L(\alpha,\delta_e) + C_L(\alpha,\delta_s)$$

$$C_y = C_y(\delta_e,\alpha,\beta) + C_y(\alpha,\delta_{\alpha_{Right}}) - C_y(\alpha,\delta_{\alpha_{Left}})$$

$$+ \mathrm{sgn}\ \delta_\alpha C_y(\alpha,\delta_e) + C_{y_{\delta_r}}(\alpha)\cdot\delta_r$$

$$C_D = C_D(\alpha,\delta_e) + C_D(\alpha,\delta_s)$$

C. DATA TABLES

The original data package provided by the USAF Flight Dynamics Lab presented the coefficients in stability axis form. To be compatible with the body axis system employed in this study, the data were converted via a standard axis transformation.

Selected lateral-directional coefficients were plotted as a function of α to check for inconsistencies in the digitized data. As a result, several errors were found in the original data. These have been corrected in the data presented here. The digitized body axis coefficients are presented first. They are followed by plots of:

$C_{\ell_B}(\delta_e,\alpha,\beta)$	$C_{\ell_{p_B}}(\alpha)$
$C_{n_B}(\delta_e,\alpha,\beta)$	$C_{\ell_{r_B}}(\alpha)$
$C_y(\delta_e,\alpha,\beta)$	$C_{n_{p_B}}(\alpha)$
	$C_{n_{r_B}}(\alpha)$

The following is a guide to the non-linear (scheduled) aerodynamic coefficients and their digitization grids. Coefficients for negative β's are taken to have the opposite sign.

Grid No. 1

$C_\ell(\delta_e,\alpha,\beta)$
$C_n(\delta_e,\alpha,\beta)$
$C_y(\delta_e,\alpha,\beta)$

α from 0 to 90 deg in steps of 2.5 deg	(37 points)
δ_e of −25 deg, −20 deg, −15 deg, −5 deg	(4 points)
β of 2 deg, 4 deg, 6 deg, 8 deg, 10 deg, 20 deg, 25 deg, 30 deg, 90 deg	(10 points)

Grid No. 2

Same α and δ_e as Grid No. 1.

$C_L(\alpha,\delta_e)$

$C_m(\alpha,\delta_e)$

$C_D(\alpha,\delta_e)$

$C_{m_Q}(\alpha,\delta_e)$

$C_{m_{\dot{\alpha}}}(\alpha,\delta_e)$

Grid No. 3

Same α as Grid No. 1.

$C_{\ell_p}(\alpha)$

$C_{\ell_r}(\alpha)$

$C_{n_p}(\alpha)$

$C_{n_r}(\alpha)$

Grid No. 4

$C_\ell(\alpha,\delta_a)$ (Simultaneous left deflections occur with opposite sign moments — same for Grids No. 5-8.)

$C_n(\alpha,\delta_a)$

α of 0, 2 deg, 4 deg, 6 deg, 10 deg, 14 deg, 16 deg, 18 deg, 20 deg, 22 deg, 24 deg, 26 deg, 30 deg, 35 deg, 40 deg, 45 deg, 50 deg, 90 deg (18 points)

δ_a from −25 deg to +25 deg in steps of 5 deg (11 points)

Grid No. 5

$C_m(\alpha,\delta_a)$

Same δ_a as in Grid No. 4.

α of 0 deg, 2 deg, 4 deg, 6 deg, 10 deg, 14 deg, 16 deg, 90 deg

Grid No. 6

$C_y(\alpha, \delta_a)$

Same α as in Grid No. 5.

δ_a of +25 deg and −25 deg

Grid No. 7

$C_L(\alpha, \delta_s)$[LIFT]

$C_D(\alpha, \delta_s)$

$C_m(\alpha, \delta_s)$

$C_y(\alpha, \delta_s)$

Same α as in Grid No. 5.

δ_s at 0 deg and 60 deg

Grid No. 8

$C_\ell(\alpha, \delta_s)$

$C_n(\alpha, \delta_s)$

Same α as Grid No. 4 except for additional α = 70 deg point (19 points)

δ_s from 0 deg to 60 deg in 10 deg steps (7 points)

Grid No. 9

$C_{y_{\delta_r}}(\alpha)$

$C_{\ell_{\delta_r}}(\alpha)$

$C_{n_{\delta_r}}(\alpha)$

α from 0 to 90 deg in steps of 5 deg (19 points)

CL(DE,ALPHA,BETA) ROLL COEFF. IN BODY COORD.

DE= -25.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0019	-.0039	-.0057	-.0075	-.0096	-.0142	-.0191	-.0232	-.0210	-.0210
2.5	-.0027	-.0055	-.0081	-.0109	-.0137	-.0206	-.0281	-.0330	-.0302	-.0302
5.0	-.0035	-.0072	-.0106	-.0143	-.0181	-.0258	-.0372	-.0421	-.0398	-.0398
7.5	-.0042	-.0084	-.0129	-.0170	-.0215	-.0319	-.0441	-.0485	-.0464	-.0467
10.0	-.0047	-.0094	-.0143	-.0188	-.0237	-.0352	-.0469	-.0512	-.0493	-.0493
12.5	-.0049	-.0098	-.0137	-.0190	-.0242	-.0359	-.0432	-.0481	-.0472	-.0472
15.0	-.0041	-.0084	-.0130	-.0182	-.0216	-.0333	-.0377	-.0366	-.0345	-.0345
17.5	-.0022	-.0051	-.0091	-.0127	-.0144	-.0206	-.0249	-.0220	-.0169	-.0169
20.0	-.0004	-.0022	-.0043	-.0052	-.0044	-.0075	-.0134	-.0124	-.0077	-.0077
22.5	.0009	.0007	.0006	.0009	.0003	-.0035	-.0089	-.0082	-.0032	-.0032
25.0	.0010	.0012	.0011	.0007	.0010	-.0110	-.0131	-.0115	-.0057	-.0057
27.5	-.0002	-.0031	-.0060	-.0096	-.0098	-.0221	-.0208	-.0181	-.0126	-.0126
30.0	-.0018	-.0092	-.0177	-.0270	-.0272	-.0248	-.0242	-.0212	-.0163	-.0163
32.5	-.0023	-.0102	-.0203	-.0278	-.0305	-.0266	-.0268	-.0233	-.0207	-.0207
35.0	-.0021	-.0095	-.0191	-.0246	-.0273	-.0258	-.0278	-.0251	-.0248	-.0248
37.5	-.0018	-.0084	-.0169	-.0211	-.0227	-.0222	-.0275	-.0270	-.0287	-.0287
40.0	-.0015	-.0071	-.0140	-.0177	-.0180	-.0192	-.0271	-.0297	-.0326	-.0326
42.5	-.0021	-.0064	-.0122	-.0143	-.0158	-.0200	-.0283	-.0339	-.0376	-.0376
45.0	-.0025	-.0065	-.0109	-.0124	-.0158	-.0229	-.0302	-.0387	-.0431	-.0431
47.5	-.0033	-.0074	-.0117	-.0144	-.0172	-.0267	-.0340	-.0429	-.0488	-.0488
50.0	-.0042	-.0087	-.0132	-.0176	-.0193	-.0308	-.0386	-.0468	-.0534	-.0534
52.5	-.0049	-.0100	-.0145	-.0202	-.0211	-.0340	-.0407	-.0494	-.0570	-.0570
55.0	-.0059	-.0117	-.0166	-.0230	-.0226	-.0365	-.0428	-.0515	-.0600	-.0600
57.5	-.0070	-.0133	-.0185	-.0252	-.0243	-.0384	-.0449	-.0532	-.0628	-.0628
60.0	-.0078	-.0147	-.0201	-.0273	-.0255	-.0398	-.0466	-.0549	-.0647	-.0647
62.5	-.0083	-.0159	-.0215	-.0287	-.0267	-.0410	-.0485	-.0556	-.0662	-.0662
65.0	-.0087	-.0168	-.0223	-.0297	-.0274	-.0417	-.0506	-.0568	-.0673	-.0673
67.5	-.0091	-.0174	-.0225	-.0302	-.0280	-.0424	-.0519	-.0579	-.0680	-.0680
70.0	-.0090	-.0173	-.0223	-.0301	-.0282	-.0430	-.0530	-.0591	-.0682	-.0682
72.5	-.0088	-.0172	-.0219	-.0297	-.0283	-.0439	-.0538	-.0596	-.0688	-.0688
75.0	-.0086	-.0168	-.0210	-.0290	-.0284	-.0440	-.0543	-.0598	-.0683	-.0683
77.5	-.0082	-.0161	-.0201	-.0284	-.0285	-.0438	-.0543	-.0594	-.0676	-.0676
80.0	-.0079	-.0154	-.0191	-.0273	-.0286	-.0432	-.0538	-.0591	-.0666	-.0666
82.5	-.0076	-.0146	-.0181	-.0263	-.0287	-.0425	-.0532	-.0584	-.0656	-.0656
85.0	-.0073	-.0137	-.0170	-.0250	-.0289	-.0417	-.0520	-.0575	-.0643	-.0643
87.5	-.0070	-.0131	-.0163	-.0240	-.0292	-.0409	-.0505	-.0567	-.0634	-.0634
90.0	-.0068	-.0123	-.0154	-.0229	-.0298	-.0398	-.0488	-.0551	-.0627	-.0627

DE= -20.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0019	-.0039	-.0057	-.0075	-.0096	-.0142	-.0191	-.0232	-.0210	-.0210
2.5	-.0027	-.0055	-.0081	-.0109	-.0137	-.0206	-.0281	-.0330	-.0302	-.0302
5.0	-.0035	-.0072	-.0106	-.0143	-.0181	-.0258	-.0372	-.0421	-.0398	-.0398
7.5	-.0042	-.0084	-.0129	-.0170	-.0215	-.0319	-.0441	-.0480	-.0459	-.0459
10.0	-.0047	-.0094	-.0143	-.0188	-.0237	-.0352	-.0469	-.0496	-.0476	-.0476
12.5	-.0049	-.0098	-.0137	-.0189	-.0241	-.0356	-.0433	-.0466	-.0429	-.0430
15.0	-.0041	-.0085	-.0131	-.0183	-.0222	-.0333	-.0388	-.0374	-.0328	-.0328
17.5	-.0023	-.0056	-.0097	-.0135	-.0161	-.0219	-.0280	-.0244	-.0188	-.0188
20.0	-.0008	-.0028	-.0053	-.0069	-.0064	-.0095	-.0168	-.0157	-.0110	-.0110
22.5	.0006	.0001	-.0006	-.0010	-.0015	-.0056	-.0126	-.0112	-.0060	-.0060
25.0	.0007	.0003	-.0006	-.0015	-.0022	-.0135	-.0164	-.0142	-.0080	-.0080
27.5	-.0006	-.0042	-.0078	-.0129	-.0127	-.0234	-.0224	-.0198	-.0139	-.0139
30.0	-.0019	-.0097	-.0183	-.0275	-.0282	-.0262	-.0261	-.0231	-.0183	-.0183
32.5	-.0024	-.0105	-.0207	-.0281	-.0312	-.0275	-.0286	-.0252	-.0227	-.0227
35.0	-.0021	-.0096	-.0194	-.0246	-.0279	-.0272	-.0293	-.0268	-.0263	-.0263

37.5	-.0018	-.0085	-.0171	-.0211	-.0227	-.0233	-.0287	-.0289	-.0300	-.0300
40.0	-.0017	-.0071	-.0142	-.0177	-.0180	-.0201	-.0282	-.0314	-.0339	-.0339
42.5	-.0021	-.0064	-.0122	-.0143	-.0158	-.0205	-.0289	-.0348	-.0383	-.0383
45.0	-.0025	-.0065	-.0109	-.0124	-.0158	-.0229	-.0305	-.0390	-.0434	-.0434
47.5	-.0033	-.0074	-.0117	-.0144	-.0172	-.0267	-.0344	-.0429	-.0488	-.0488
50.0	-.0042	-.0087	-.0132	-.0176	-.0193	-.0308	-.0386	-.0468	-.0534	-.0534
52.5	-.0049	-.0100	-.0145	-.0202	-.0211	-.0340	-.0412	-.0494	-.0570	-.0570
55.0	-.0059	-.0117	-.0166	-.0230	-.0226	-.0365	-.0433	-.0515	-.0600	-.0600
57.5	-.0070	-.0133	-.0185	-.0252	-.0243	-.0384	-.0455	-.0532	-.0628	-.0628
60.0	-.0078	-.0147	-.0201	-.0273	-.0255	-.0398	-.0473	-.0549	-.0647	-.0647
62.5	-.0083	-.0159	-.0215	-.0287	-.0267	-.0410	-.0489	-.0556	-.0662	-.0662
65.0	-.0087	-.0168	-.0223	-.0297	-.0274	-.0417	-.0506	-.0568	-.0673	-.0673
67.5	-.0091	-.0174	-.0225	-.0302	-.0280	-.0424	-.0519	-.0579	-.0680	-.0680
70.0	-.0090	-.0173	-.0223	-.0301	-.0282	-.0430	-.0530	-.0591	-.0682	-.0682
72.5	-.0088	-.0172	-.0219	-.0297	-.0283	-.0439	-.0538	-.0596	-.0688	-.0688
75.0	-.0086	-.0168	-.0210	-.0290	-.0284	-.0440	-.0543	-.0598	-.0683	-.0683
77.5	-.0082	-.0161	-.0201	-.0284	-.0285	-.0438	-.0543	-.0594	-.0676	-.0676
80.0	-.0079	-.0154	-.0191	-.0273	-.0286	-.0432	-.0538	-.0591	-.0666	-.0666
82.5	-.0076	-.0146	-.0181	-.0263	-.0287	-.0425	-.0532	-.0584	-.0656	-.0656
85.0	-.0073	-.0137	-.0170	-.0250	-.0289	-.0417	-.0520	-.0575	-.0643	-.0643
87.5	-.0070	-.0131	-.0163	-.0240	-.0292	-.0409	-.0505	-.0567	-.0634	-.0634
90.0	-.0068	-.0123	-.0154	-.0229	-.0298	-.0398	-.0488	-.0551	-.0627	-.0627

DE= -15.0

BETA ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0019	-.0039	-.0057	-.0075	-.0096	-.0142	-.0191	-.0232	-.0210	-.0210
2.5	-.0027	-.0055	-.0081	-.0109	-.0137	-.0206	-.0281	-.0330	-.0302	-.0302
5.0	-.0035	-.0072	-.0106	-.0143	-.0181	-.0258	-.0372	-.0421	-.0398	-.0398
7.5	-.0042	-.0084	-.0129	-.0170	-.0215	-.0319	-.0441	-.0475	-.0454	-.0454
10.0	-.0047	-.0094	-.0143	-.0188	-.0237	-.0352	-.0469	-.0483	-.0463	-.0463
12.5	-.0049	-.0098	-.0137	-.0189	-.0240	-.0353	-.0435	-.0457	-.0418	-.0418
15.0	-.0041	-.0086	-.0133	-.0187	-.0222	-.0345	-.0393	-.0383	-.0337	-.0337
17.5	-.0024	-.0062	-.0100	-.0142	-.0174	-.0226	-.0300	-.0270	-.0232	-.0232
20.0	-.0011	-.0036	-.0063	-.0085	-.0087	-.0115	-.0200	-.0185	-.0145	-.0145
22.5	.0002	-.0008	-.0014	-.0027	-.0037	-.0080	-.0158	-.0146	-.0097	-.0097
25.0	.0002	-.0008	-.0021	-.0029	-.0053	-.0164	-.0199	-.0177	-.0118	-.0118
27.5	-.0011	-.0052	-.0101	-.0145	-.0165	-.0254	-.0247	-.0223	-.0170	-.0170
30.0	-.0023	-.0101	-.0191	-.0275	-.0294	-.0277	-.0281	-.0256	-.0206	-.0206
32.5	-.0024	-.0108	-.0212	-.0281	-.0314	-.0290	-.0306	-.0275	-.0245	-.0245
35.0	-.0021	-.0099	-.0200	-.0246	-.0284	-.0285	-.0312	-.0287	-.0280	-.0280
37.5	-.0018	-.0085	-.0174	-.0211	-.0227	-.0244	-.0304	-.0304	-.0315	-.0315
40.0	-.0018	-.0071	-.0144	-.0177	-.0180	-.0208	-.0295	-.0325	-.0352	-.0352
42.5	-.0021	-.0064	-.0122	-.0143	-.0158	-.0209	-.0300	-.0359	-.0389	-.0389
45.0	-.0025	-.0065	-.0109	-.0124	-.0158	-.0229	-.0316	-.0399	-.0438	-.0438
47.5	-.0033	-.0074	-.0117	-.0144	-.0172	-.0267	-.0348	-.0437	-.0488	-.0488
50.0	-.0042	-.0087	-.0132	-.0176	-.0193	-.0308	-.0386	-.0468	-.0534	-.0534
52.5	-.0049	-.0100	-.0145	-.0202	-.0211	-.0340	-.0415	-.0494	-.0570	-.0570
55.0	-.0059	-.0117	-.0166	-.0230	-.0226	-.0365	-.0439	-.0515	-.0600	-.0600
57.5	-.0070	-.0133	-.0185	-.0252	-.0243	-.0384	-.0459	-.0532	-.0628	-.0628
60.0	-.0078	-.0147	-.0201	-.0273	-.0255	-.0398	-.0478	-.0549	-.0647	-.0647
62.5	-.0083	-.0159	-.0215	-.0287	-.0267	-.0410	-.0493	-.0556	-.0662	-.0662
65.0	-.0087	-.0168	-.0223	-.0297	-.0274	-.0417	-.0506	-.0568	-.0673	-.0673
67.5	-.0091	-.0174	-.0225	-.0302	-.0280	-.0424	-.0519	-.0579	-.0680	-.0680
70.0	-.0090	-.0173	-.0223	-.0301	-.0282	-.0430	-.0530	-.0591	-.0682	-.0682
72.5	-.0088	-.0172	-.0219	-.0297	-.0283	-.0439	-.0538	-.0596	-.0688	-.0688
75.0	-.0086	-.0168	-.0210	-.0290	-.0284	-.0440	-.0543	-.0598	-.0683	-.0683
77.5	-.0082	-.0161	-.0201	-.0284	-.0285	-.0438	-.0543	-.0594	-.0676	-.0676
80.0	-.0079	-.0154	-.0191	-.0273	-.0286	-.0432	-.0538	-.0591	-.0666	-.0666
82.5	-.0076	-.0146	-.0181	-.0263	-.0287	-.0425	-.0532	-.0584	-.0656	-.0656

85.0	-.0073	-.0137	-.0170	-.0250	-.0289	-.0417	-.0520	-.0575	-.0643	-.0643
87.5	-.0070	-.0131	-.0163	-.0240	-.0292	-.0409	-.0505	-.0567	-.0634	-.0634
90.0	-.0068	-.0123	-.0154	-.0229	-.0298	-.0398	-.0488	-.0551	-.0627	-.0627

DE= -5.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0019	-.0039	-.0057	-.0075	-.0096	-.0142	-.0191	-.0232	-.0210	-.0210
2.5	-.0027	-.0055	-.0081	-.0109	-.0137	-.0206	-.0281	-.0330	-.0302	-.0302
5.0	-.0035	-.0072	-.0106	-.0143	-.0181	-.0258	-.0372	-.0421	-.0398	-.0398
7.5	-.0042	-.0084	-.0129	-.0170	-.0215	-.0319	-.0441	-.0475	-.0454	-.0454
10.0	-.0047	-.0094	-.0143	-.0188	-.0237	-.0352	-.0469	-.0483	-.0463	-.0463
12.5	-.0049	-.0096	-.0136	-.0188	-.0237	-.0349	-.0438	-.0459	-.0418	-.0418
15.0	-.0041	-.0089	-.0135	-.0189	-.0233	-.0362	-.0398	-.0391	-.0345	-.0345
17.5	-.0028	-.0073	-.0110	-.0160	-.0191	-.0291	-.0345	-.0310	-.0269	-.0269
20.0	-.0015	-.0046	-.0077	-.0108	-.0122	-.0174	-.0231	-.0225	-.0195	-.0195
22.5	-.0004	-.0020	-.0036	-.0059	-.0080	-.0134	-.0197	-.0186	-.0150	-.0150
25.0	-.0004	-.0028	-.0050	-.0086	-.0110	-.0225	-.0244	-.0218	-.0175	-.0175
27.5	-.0016	-.0073	-.0134	-.0198	-.0236	-.0287	-.0295	-.0266	-.0224	-.0224
30.0	-.0029	-.0110	-.0213	-.0282	-.0308	-.0299	-.0329	-.0291	-.0255	-.0255
32.5	-.0027	-.0116	-.0226	-.0283	-.0322	-.0315	-.0344	-.0308	-.0290	-.0290
35.0	-.0021	-.0106	-.0209	-.0246	-.0295	-.0312	-.0345	-.0317	-.0322	-.0322
37.5	-.0018	-.0088	-.0178	-.0211	-.0231	-.0266	-.0333	-.0332	-.0351	-.0351
40.0	-.0020	-.0071	-.0148	-.0177	-.0180	-.0220	-.0316	-.0349	-.0380	-.0380
42.5	-.0021	-.0064	-.0122	-.0143	-.0158	-.0213	-.0313	-.0373	-.0413	-.0413
45.0	-.0025	-.0065	-.0109	-.0124	-.0158	-.0229	-.0325	-.0405	-.0450	-.0450
47.5	-.0033	-.0074	-.0117	-.0144	-.0172	-.0267	-.0354	-.0437	-.0488	-.0488
50.0	-.0042	-.0087	-.0132	-.0176	-.0193	-.0308	-.0386	-.0468	-.0534	-.0534
52.5	-.0049	-.0100	-.0145	-.0202	-.0211	-.0340	-.0418	-.0494	-.0570	-.0570
55.0	-.0059	-.0117	-.0166	-.0230	-.0226	-.0365	-.0444	-.0515	-.0600	-.0600
57.5	-.0070	-.0133	-.0185	-.0252	-.0243	-.0384	-.0465	-.0532	-.0628	-.0628
60.0	-.0078	-.0147	-.0201	-.0273	-.0255	-.0398	-.0483	-.0549	-.0647	-.0647
62.5	-.0083	-.0159	-.0215	-.0287	-.0267	-.0410	-.0496	-.0556	-.0662	-.0662
65.0	-.0087	-.0168	-.0223	-.0297	-.0274	-.0417	-.0506	-.0568	-.0673	-.0673
67.5	-.0091	-.0174	-.0225	-.0302	-.0280	-.0424	-.0519	-.0579	-.0680	-.0680
70.0	-.0090	-.0173	-.0223	-.0301	-.0282	-.0430	-.0539	-.0591	-.0682	-.0682
72.5	-.0088	-.0172	-.0219	-.0297	-.0283	-.0439	-.0538	-.0596	-.0688	-.0688
75.0	-.0086	-.0163	-.0210	-.0290	-.0284	-.0440	-.0543	-.0598	-.0683	-.0683
77.5	-.0082	-.0161	-.0201	-.0284	-.0285	-.0438	-.0543	-.0594	-.0676	-.0676
80.0	-.0079	-.0154	-.0191	-.0273	-.0286	-.0432	-.0538	-.0591	-.0666	-.0666
82.5	-.0076	-.0146	-.0181	-.0263	-.0287	-.0425	-.0532	-.0584	-.0656	-.0656
85.0	-.0073	-.0137	-.0170	-.0250	-.0289	-.0417	-.0520	-.0575	-.0643	-.0643
87.5	-.0070	-.0131	-.0163	-.0240	-.0292	-.0409	-.0505	-.0567	-.0634	-.0634
90.0	-.0068	-.0123	-.0154	-.0229	-.0298	-.0398	-.0488	-.0551	-.0627	-.0627

CN(DE,ALPHA,BETA) YAW COEFF. IN BODY COORD.

DE= -25.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	.0037	.0082	.0137	.0193	.0261	.0410	.0535	.0494	.0400	.0400
2.5	.0037	.0084	.0137	.0195	.0262	.0411	.0607	.0560	.0493	.0493
5.0	.0037	.0083	.0137	.0195	.0262	.0410	.0612	.0562	.0535	.0535
7.5	.0035	.0081	.0134	.0193	.0258	.0406	.0541	.0498	.0497	.0496
10.0	.0034	.0081	.0133	.0190	.0255	.0404	.0419	.0384	.0379	.0379
12.5	.0039	.0089	.0112	.0219	.0310	.0496	.0248	.0213	.0152	.0152
15.0	.0028	.0062	.0090	.0125	.0112	.0187	.0071	.0015	-.0064	-.0064
17.5	.0012	.0024	.0023	.0010	-.0082	-.0154	-.0105	-.0150	-.0213	-.0213
20.0	-.0008	-.0026	-.0060	-.0089	-.0186	-.0244	-.0233	-.0267	-.0312	-.0312
22.5	-.0031	-.0076	-.0140	-.0183	-.0224	-.0308	-.0336	-.0359	-.0399	-.0399
25.0	-.0040	-.0084	-.0139	-.0184	-.0236	-.0368	-.0420	-.0442	-.0470	-.0470
27.5	-.0037	-.0087	-.0163	-.0217	-.0277	-.0441	-.0471	-.0500	-.0516	-.0516
30.0	-.0035	-.0099	-.0214	-.0292	-.0355	-.0463	-.0501	-.0522	-.0541	-.0541
32.5	-.0028	-.0090	-.0212	-.0280	-.0355	-.0457	-.0506	-.0528	-.0550	-.0550
35.0	-.0017	-.0072	-.0184	-.0238	-.0309	-.0431	-.0492	-.0514	-.0551	-.0551
37.5	-.0010	-.0057	-.0145	-.0197	-.0248	-.0368	-.0459	-.0499	-.0548	-.0548
40.0	-.0004	-.0044	-.0101	-.0151	-.0179	-.0301	-.0421	-.0475	-.0542	-.0542
42.5	-.0005	-.0033	-.0065	-.0107	-.0134	-.0251	-.0384	-.0452	-.0531	-.0531
45.0	-.0003	-.0024	-.0034	-.0067	-.0105	-.0208	-.0357	-.0432	-.0518	-.0518
47.5	.0002	-.0019	-.0017	-.0047	-.0090	-.0184	-.0335	-.0424	-.0516	-.0516
50.0	.0008	-.0017	-.0011	-.0035	-.0086	-.0170	-.0315	-.0421	-.0515	-.0515
52.5	.0006	-.0019	-.0015	-.0029	-.0086	-.0156	-.0303	-.0411	-.0510	-.0510
55.0	.0002	-.0027	-.0022	-.0037	-.0091	-.0146	-.0280	-.0392	-.0498	-.0498
57.5	-.0004	-.0037	-.0039	-.0054	-.0102	-.0138	-.0251	-.0363	-.0480	-.0480
60.0	-.0015	-.0051	-.0065	-.0073	-.0116	-.0132	-.0219	-.0327	-.0458	-.0458
62.5	-.0027	-.0064	-.0089	-.0097	-.0132	-.0125	-.0188	-.0296	-.0431	-.0431
65.0	-.0037	.0077	-.0109	-.0118	-.0145	-.0122	-.0160	-.0262	-.0403	-.0403
67.5	-.0044	-.0085	-.0127	-.0134	-.0155	-.0119	-.0139	-.0231	-.0373	-.0373
70.0	-.0049	-.0090	-.0136	-.0145	-.0158	-.0118	-.0126	-.0208	-.0345	-.0345
72.5	-.0050	-.0091	-.0136	-.0145	-.0157	-.0116	-.0120	-.0190	-.0312	-.0312
75.0	-.0050	-.0089	-.0132	-.0143	-.0153	-.0117	-.0115	-.0171	-.0278	-.0278
77.5	-.0048	-.0081	-.0122	-.0134	-.0145	-.0118	-.0112	-.0153	-.0240	-.0240
80.0	-.0044	-.0072	-.0108	-.0121	-.0134	-.0118	-.0111	-.0135	-.0195	-.0195
82.5	-.0038	-.0059	-.0083	-.0102	-.0120	-.0118	-.0110	-.0117	-.0145	-.0145
85.0	-.0027	-.0040	-.0062	-.0079	-.0102	-.0114	-.0108	-.0094	-.0086	-.0086
87.5	-.0018	-.0018	-.0031	-.0058	-.0080	-.0109	-.0107	-.0071	-.0024	-.0024
90.0	-.0004	.0002	.0002	-.0012	-.0054	-.0103	-.0105	-.0050	.0040	-.0040

DE= -20.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	.0037	.0082	.0137	.0193	.0261	.0410	.0535	.0494	.0400	.0400
2.5	.0037	.0084	.0137	.0195	.0262	.0411	.0607	.0560	.0493	.0493
5.0	.0037	.0083	.0137	.0195	.0262	.0410	.0612	.0562	.0535	.0535
7.5	.0035	.0081	.0134	.0193	.0258	.0406	.0541	[illegible]	.0497	.0497
10.0	.0034	.0081	.0133	.0190	.0255	.0404	.0419	.0387	.0382	.0382
12.5	.0039	.0089	.0110	.0216	.0306	.0484	.0254	.0227	.0162	.0162
15.0	.0028	.0066	.0096	.0132	.0132	.0187	.0110	.0043	-.0031	-.0031
17.5	.0012	.0033	.0039	.0037	-.0042	-.0115	-.0038	-.0101	-.0219	-.0219
20.0	-.0003	-.0021	-.0038	-.0054	-.0151	-.0221	-.0168	-.0207	-.0261	-.0261
22.5	-.0028	-.0069	-.0116	-.0156	-.0205	-.0291	-.0278	-.0317	-.0357	-.0357

25.0	-.0038	-.0082	-.0132	-.0181	-.0228	-.0364	-.0377	-.0401	-.0443	-.0443
27.5	-.0037	-.0087	-.0160	-.0218	-.0273	-.0433	-.0440	-.0468	-.0501	-.0501
30.0	-.0034	-.0096	-.0211	-.0284	-.0344	-.0452	-.0467	-.0489	-.0517	-.0517
32.5	-.0028	-.0088	-.0211	-.0275	-.0344	-.0455	-.0478	-.0497	-.0533	-.0533
35.0	-.0017	-.0072	-.0186	-.0238	-.0305	-.0424	-.0471	-.0488	-.0537	-.0537
37.5	-.0010	-.0057	-.0146	-.0197	-.0248	-.0362	-.0444	-.0474	-.0535	-.0535
40.0	-.0005	-.0044	-.0102	-.0151	-.0179	-.0294	-.0408	-.0455	-.0533	-.0533
42.5	-.0005	-.0033	-.0065	-.0107	-.0134	-.0245	-.0377	-.0441	-.0523	-.0523
45.0	-.0003	-.0024	-.0034	-.0067	-.0105	-.0208	-.0354	-.0429	-.0515	-.0515
47.5	.0002	-.0019	-.0017	-.0047	-.0090	-.0184	-.0332	-.0424	-.0516	-.0516
50.0	.0008	-.0017	-.0011	-.0035	-.0086	-.0170	-.0315	-.0421	-.0515	-.0515
52.5	.0006	-.0019	-.0015	-.0029	-.0086	-.0156	-.0299	-.0411	-.0510	-.0510
55.0	.0002	-.0027	-.0022	-.0037	-.0091	-.0146	-.0277	-.0392	-.0498	-.0498
57.5	-.0004	-.0037	-.0039	-.0054	-.0102	-.0138	-.0247	-.0363	-.0489	-.0480
60.0	-.0015	-.0051	-.0065	-.0073	-.0116	-.0132	-.0215	-.0327	-.0458	-.0458
62.5	-.0027	-.0064	-.0089	-.0097	-.0132	-.0125	-.0186	-.0296	-.0431	-.0431
65.0	-.0037	-.0077	-.0109	-.0118	-.0145	-.0122	-.0160	-.0262	-.0403	-.0403
67.5	-.0044	-.0085	-.0127	-.0134	-.0155	-.0119	-.0139	-.0231	-.0373	-.0373
70.0	-.0049	-.0090	-.0136	-.0145	-.0158	-.0118	-.0126	-.0208	-.0345	-.0345
72.5	-.0050	-.0091	-.0136	-.0145	-.0157	-.0116	-.0120	-.0190	-.0312	-.0312
75.0	-.0050	-.0089	-.0132	-.0143	-.0153	-.0117	-.0115	-.0171	-.0278	-.0278
77.5	-.0048	-.0081	-.0122	-.0134	-.0145	-.0118	-.0112	-.0153	-.0240	-.0240
80.0	-.0044	-.0072	-.0108	-.0121	-.0134	-.0118	-.0111	-.0135	-.0195	-.0195
82.5	-.0038	-.0059	-.0088	-.0102	-.0120	-.0118	-.0110	-.0117	-.0145	-.0145
85.0	-.0027	-.0040	-.0062	-.0079	-.0102	-.0114	-.0108	-.0094	-.0086	-.0086
87.5	-.0018	-.0018	-.0031	-.0058	-.0080	-.0109	-.0107	-.0071	-.0024	-.0024
90.0	-.0004	.0002	.0002	-.0012	-.0054	-.0103	-.0105	-.0050	.0040	-.0040

DE= -15.0

BETA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
ALPHA										
0.	.0037	.0082	.0137	.0193	.0261	.0410	.0535	.0494	.0400	.0400
2.5	.0037	.0084	.0137	.0195	.0262	.0411	.0607	.0560	.0493	.0493
5.0	.0037	.0083	.0137	.0195	.0262	.0410	.0612	.0562	.0535	.0535
7.5	.0035	.0081	.0134	.0193	.0258	.0406	.0541	.0499	.0498	.0498
10.0	.0034	.0081	.0133	.0190	.0255	.0404	.0419	.0389	.0384	.0384
12.5	.0039	.0089	.0110	.0214	.0301	.0471	.0263	.0235	.0165	.0165
15.0	.0028	.0070	.0101	.0145	.0132	.0232	.0131	.0077	.0001	.0001
17.5	.0011	.0041	.0044	.0058	-.0015	-.0092	.0001	-.0058	-.0113	-.0113
20.0	.0000	-.0013	-.0023	-.0031	-.0107	-.0183	-.0113	-.0160	-.0213	-.0213
22.5	-.0023	-.0057	-.0104	-.0130	-.0183	-.0270	-.0226	-.0262	-.0291	-.0291
25.0	-.0034	-.0079	-.0128	-.0179	-.0217	-.0352	-.0328	-.0353	-.0386	-.0386
27.5	-.0036	-.0084	-.0165	-.0219	-.0271	-.0423	-.0397	-.0421	-.0458	-.0458
30.0	-.0035	-.0093	-.0206	-.0284	-.0334	-.0443	-.0433	-.0447	-.0489	-.0489
32.5	-.0029	-.0087	-.0209	-.0275	-.0341	-.0442	-.0447	-.0461	-.0513	-.0513
35.0	-.0017	-.0074	-.0185	-.0238	-.0309	-.0416	-.0443	-.0461	-.0521	-.0521
37.5	-.0010	-.0058	-.0148	-.0197	-.0248	-.0355	-.0422	-.0454	-.0524	-.0524
40.0	-.0006	-.0044	-.0104	-.0151	-.0179	-.0290	-.0392	-.0441	-.0521	-.0521
42.5	-.0005	-.0033	-.0065	-.0107	-.0134	-.0241	-.0366	-.0430	-.0517	-.0517
45.0	-.0003	-.0024	-.0034	-.0067	-.0105	-.0208	-.0343	-.0420	-.0511	-.0511
47.5	.0002	-.0019	-.0017	-.0047	-.0090	-.0184	-.0328	-.0418	-.0516	-.0516
50.0	.0008	-.0017	-.0011	-.0035	-.0086	-.0170	-.0315	-.0421	-.0515	-.0515
52.5	.0006	-.0019	-.0015	-.0029	-.0086	-.0156	-.0296	-.0411	-.0510	-.0510
55.0	.0002	-.0027	-.0022	-.0037	-.0091	-.0146	-.0273	-.0392	-.0498	-.0498

57.5	-.0004	-.0037	-.0039	-.0054	-.0102	-.0138	-.0245	-.0363	-.0480	-.0480
60.0	-.0015	-.0051	-.0065	-.0073	-.0116	-.0132	-.0212	-.0327	-.0458	-.0458
62.5	-.0027	-.0064	-.0089	-.0097	-.0132	-.0125	-.0184	-.0296	-.0431	-.0431
65.0	-.0037	-.0077	-.0109	-.0118	-.0145	-.0122	-.0160	-.0262	-.0403	-.0403
67.5	-.0044	-.0085	-.0127	-.0134	-.0155	-.0119	-.0139	-.0231	-.0373	-.0373
70.0	-.0049	-.0090	-.0136	-.0145	-.0158	-.0118	-.0126	-.0208	-.0345	-.0345
72.5	-.0050	-.0091	-.0136	-.0145	-.0157	-.0116	-.0120	-.0190	-.0312	-.0312
75.0	-.0050	-.0089	-.0132	-.0143	-.0153	-.0117	-.0115	-.0171	-.0278	-.0278
77.5	-.0048	-.0081	-.0122	-.0134	-.0145	-.0118	-.0112	-.0153	-.0240	-.0240
80.0	-.0044	-.0072	-.0108	-.0121	-.0134	-.0118	-.0111	-.0135	-.0195	-.0195
82.5	-.0038	-.0059	-.0088	-.0102	-.0120	-.0118	-.0110	-.0117	-.0145	-.0145
85.0	-.0027	-.0040	-.0062	-.0079	-.0102	-.0114	-.0108	-.0094	-.0086	-.0086
87.5	-.0018	-.0018	-.0031	-.0058	-.0080	-.0109	-.0107	-.0071	-.0024	-.0024
90.0	-.0004	.0002	.0002	-.0012	-.0054	-.0103	-.0105	-.0050	.0040	-.0040

DE= -5.0

BETA ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	.0037	.0082	.0137	.0193	.0261	.0410	.0535	.0494	.0400	.0400
2.5	.0037	.0084	.0137	.0195	.0262	.0411	.0607	.0560	.0493	.0493
5.0	.0037	.0083	.0137	.0195	.0262	.0410	.0612	.0562	.0535	.0535
7.5	.0035	.0081	.0134	.0193	.0258	.0406	.0541	.0499	.0498	.0498
10.0	.0034	.0081	.0133	.0190	.0255	.0404	.0419	.0389	.0384	.0384
12.5	.0039	.0083	.0105	.0210	.0289	.0450	.0274	.0247	.0165	.0165
15.0	.0028	.0080	.0109	.0153	.0174	.0297	.0149	.0108	.0032	.0032
17.5	.0018	.0059	.0061	.0081	.0029	.0050	.0094	[illegible]	-.0059	-.0059
20.0	.0006	.0007	.0003	.0005	-.0044	-.0102	-.0084	-.0103	-.0142	-.0142
22.5	-.0017	-.0041	-.0068	-.0074	-.0120	-.0233	-.0203	-.0204	-.0216	-.0216
25.0	-.0030	-.0066	-.0109	-.0158	-.0195	-.0340	-.0278	-.0287	-.0298	-.0298
27.5	-.0034	-.0081	-.0151	-.0228	-.0284	-.0406	-.0333	-.0362	-.0371	-.0371
30.0	-.0034	-.0089	-.0190	-.0272	-.0329	-.0428	-.0371	-.0399	-.0418	-.0418
32.5	-.0028	-.0084	-.0195	-.0272	-.0333	-.0428	-.0395	-.0416	-.0448	-.0448
35.0	-.0017	-.0074	-.0181	-.0238	-.0306	-.0405	-.0404	-.0419	-.0467	-.0467
37.5	-.0010	-.0060	-.0146	-.0197	-.0243	-.0347	-.0391	-.0418	-.0482	-.0482
40.0	-.0007	-.0044	-.0107	-.0151	-.0179	-.0281	-.0367	-.0414	-.0493	-.0493
42.5	-.0005	-.0033	-.0065	-.0107	-.0134	-.0236	-.0351	-.0414	-.0504	-.0504
45.0	-.0003	-.0024	-.0034	-.0067	-.0105	-.0208	-.0334	-.0414	-.0512	-.0512
47.5	.0002	-.0019	-.0017	-.0047	-.0090	-.0184	-.0323	-.0418	-.0516	-.0516
50.0	.0008	-.0017	-.0011	-.0035	-.0086	-.0170	-.0315	-.0421	-.0515	-.0515
52.5	.0006	-.0019	-.0015	-.0029	-.0086	-.0156	-.0294	-.0411	-.0510	-.0510
55.0	.0002	-.0027	-.0022	-.0037	-.0091	-.0146	-.0269	-.0392	-.0498	-.0498
57.5	-.0004	-.0037	-.0039	-.0054	-.0102	-.0138	-.0241	-.0363	-.0480	-.0480
60.0	-.0015	-.0051	-.0065	-.0073	-.0116	-.0132	-.0209	-.0327	-.0458	-.0458
62.5	-.0027	-.0064	-.0089	-.0097	-.0132	-.0125	-.0182	-.0296	-.0431	-.0431
65.0	-.0037	-.0077	-.0109	-.0118	-.0145	-.0122	-.0160	-.0262	-.0403	-.0403
67.5	-.0044	-.0085	-.0127	-.0134	-.0155	-.0119	-.0139	-.0231	-.0373	-.0373
70.0	-.0049	-.0090	-.0136	-.0145	-.0158	-.0118	-.0126	-.0208	-.0345	-.0345
72.5	-.0050	-.0091	-.0136	-.0145	-.0157	-.0116	-.0120	-.0190	-.0312	-.0312
75.0	-.0050	-.0089	-.0132	-.0143	-.0153	-.0117	-.0115	-.0171	-.0278	-.0278
77.5	-.0048	-.0081	-.0122	-.0134	-.0145	-.0118	-.0112	-.0153	-.0240	-.0240
80.0	-.0044	-.0072	-.0108	-.0121	-.0134	-.0118	-.0111	-.0135	-.0195	-.0195
82.5	-.0038	-.0059	-.0088	-.0102	-.0120	-.0118	-.0110	-.0117	-.0145	-.0145
85.0	-.0027	-.0040	-.0062	-.0079	-.0102	-.0114	-.0108	-.0094	-.0086	-.0086
87.5	-.0018	-.0018	-.0031	-.0058	-.0080	-.0109	-.0107	-.0071	-.0024	-.0024
90.0	-.0004	.0002	.0002	-.0012	-.0054	-.0103	-.0105	-.0050	.0040	-.0040

CY(DE,ALPHA,BETA)

DE= -25.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0270	-.0520	-.0820	-.1090	-.1400	-.2710	-.3800	-.4400	-.5060	-.5060
2.5	-.0280	-.0530	-.0830	-.1100	-.1390	-.2890	-.4000	-.4660	-.5280	-.5280
5.0	-.0290	-.0540	-.0850	-.1120	-.1420	-.3030	-.4160	-.4810	-.5470	-.5470
7.5	-.0300	-.0570	-.0880	-.1160	-.1480	-.3080	-.4140	-.4860	-.5590	-.5590
10.0	-.0320	-.0590	-.0930	-.1220	-.1540	-.2950	-.3970	-.4730	-.5520	-.5520
12.5	-.0320	-.0630	-.0990	-.1310	-.1670	-.2800	-.3720	-.4490	-.5250	-.5250
15.0	-.0280	-.0670	-.1050	-.1370	-.1730	-.2630	-.3440	-.4150	-.4880	-.4880
17.5	-.0230	-.0630	-.1000	-.1310	-.1720	-.2500	-.3230	-.3870	-.4490	-.4490
20.0	-.0220	-.0610	-.0960	-.1240	-.1650	-.2400	-.3100	-.3600	-.4190	-.4190
22.5	-.0210	-.0580	-.0880	-.1190	-.1590	-.2300	-.2980	-.3440	-.3910	-.3910
25.0	-.0220	-.0560	-.0860	-.1130	-.1520	-.2270	-.2920	-.3400	-.3810	-.3810
27.5	-.0230	-.0540	-.0840	-.1120	-.1500	-.2230	-.2930	-.3430	-.3900	-.3900
30.0	-.0280	-.0550	-.0840	-.1130	-.1490	-.2250	-.3000	-.3550	-.4080	-.4080
32.5	-.0290	-.0580	-.0860	-.1130	-.1490	-.2300	-.3110	-.3700	-.4280	-.4280
35.0	-.0320	-.0600	-.0900	-.1180	-.1500	-.2370	-.3250	-.3860	-.4510	-.4510
37.5	-.0320	-.0620	-.0930	-.1230	-.1570	-.2480	-.3380	-.4060	-.4800	-.4800
40.0	-.0320	-.0650	-.0990	-.1320	-.1670	-.2620	-.3490	-.4270	-.5070	-.5070
42.5	-.0320	-.0680	-.1050	-.1420	-.1810	-.2770	-.3640	-.4470	-.5300	-.5300
45.0	-.0320	-.0700	-.1110	-.1510	-.1940	-.2900	-.3810	-.4640	-.5480	-.5480
47.5	-.0320	-.0700	-.1160	-.1560	-.2020	-.3010	-.3960	-.4740	-.5500	-.5500
50.0	-.0360	-.0710	-.1200	-.1600	-.2090	-.3100	-.4100	-.4820	-.5500	-.5500
52.5	-.0380	-.0730	-.1220	-.1630	-.2160	-.3190	-.4230	-.4900	-.5550	-.5550
55.0	-.0400	-.0790	-.1270	-.1710	-.2220	-.3280	-.4320	-.4990	-.5620	-.5620
57.5	-.0420	-.0820	-.1320	-.1780	-.2300	-.3360	-.4420	-.5080	-.5700	-.5700
60.0	-.0440	-.0880	-.1380	-.1830	-.2380	-.3420	-.4490	-.5170	-.5780	-.5780
62.5	-.0470	-.0920	-.1420	-.1910	-.2430	-.3490	-.4540	-.5220	-.5870	-.5870
65.0	-.0490	-.0980	-.1470	-.1970	-.2490	-.3550	-.4590	-.5290	-.5960	-.5960
67.5	-.0500	-.1010	-.1500	-.2010	-.2520	-.3590	-.4620	-.5330	-.6020	-.6020
70.0	-.0500	-.1040	-.1520	-.2030	-.2560	-.3620	-.4650	-.5380	-.6080	-.6080
72.5	-.0500	-.1080	-.1550	-.2040	-.2580	-.3630	-.4680	-.5390	-.6100	-.6100
75.0	-.0500	-.1100	-.1580	-.2050	-.2580	-.3630	-.4680	-.5410	-.6110	-.6110
77.5	-.0480	-.1110	-.1590	-.2040	-.2570	-.3620	-.4670	-.5410	-.6120	-.6120
80.0	-.0470	-.1120	-.1600	-.2020	-.2540	-.3610	-.4650	-.5400	-.6120	-.6120
82.5	-.0450	-.1120	-.1600	-.2000	-.2510	-.3580	-.4620	-.5380	-.6110	-.6110
85.0	-.0420	-.1120	-.1600	-.1980	-.2490	-.3530	-.4590	-.5360	-.6090	-.6090
87.5	-.0400	-.1120	-.1580	-.1930	-.2430	-.3490	-.4530	-.5320	-.6070	-.6070
90.0	-.0380	-.1120	-.1550	-.1860	-.2360	-.3420	-.4480	-.5260	-.6010	-.6010

DE= -20.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0270	-.0520	-.0820	-.1090	-.1400	-.2710	-.3800	-.4400	-.5060	-.5060
2.5	-.0280	-.0530	-.0830	-.1100	-.1390	-.2890	-.4000	-.4660	-.5280	-.5280
5.0	-.0290	-.0540	-.0850	-.1120	-.1420	-.3030	-.4160	-.4810	-.5470	-.5470
7.5	-.0300	-.0570	-.0880	-.1160	-.1480	-.3080	-.4170	-.4880	-.5590	-.5590
10.0	-.0320	-.0590	-.0930	-.1220	-.1540	-.3010	-.4060	-.4820	-.5600	-.5600
12.5	-.0320	-.0630	-.0990	-.1310	-.1670	-.2900	-.3880	-.4620	[illegible]	-.5370
15.0	-.0280	-.0670	-.1050	-.1400	-.1730	-.2770	-.3640	[illegible]	[illegible]	-.5040
17.5	-.0230	-.0630	-.1030	-.1390	-.1740	-.2600	-.3420	-.4090	-.4700	-.4700
20.0	-.0220	-.0610	-.1000	-.1320	-.1710	-.2500	-.3250	-.3800	-.4370	-.4370
22.5	-.0210	-.0580	-.0960	-.1300	-.1630	-.2400	-.3120	-.3600	-.4120	-.4120
25.0	-.0220	-.0560	-.0900	-.1270	-.1600	-.2370	-.3090	-.3550	-.4030	-.4030
27.5	-.0230	-.0540	-.0840	-.1220	-.1580	-.2340	-.3090	-.3580	-.4100	-.4100
30.0	-.0280	-.0550	-.0840	-.1220	-.1540	-.2360	-.3100	-.3660	-.4250	-.4250
32.5	-.0290	-.0580	-.0890	-.1230	-.1550	-.2370	-.3170	-.3800	-.4430	-.4430
35.0	-.0320	-.0600	-.0940	-.1270	-.1590	-.2400	-.3250	-.3970	.4660	-.4660

37.5	-.0320	-.0620	-.0990	-.1310	-.1620	-.2480	-.3380	-.4130	-.4880	-.4880
40.0	-.0320	-.0650	-.1020	-.1340	-.1680	-.2620	-.3490	-.4320	-.5100	-.5100
42.5	-.0320	-.0680	-.1110	-.1420	-.1810	-.2770	-.3640	-.4490	-.5300	-.5300
45.0	-.0320	-.0700	-.1180	-.1510	-.1940	-.2900	-.3810	-.4640	-.5480	-.5480
47.5	-.0320	-.0700	-.1190	-.1560	-.2020	-.3010	-.3960	-.4740	-.5500	-.5500
50.0	-.0360	-.0710	-.1200	-.1600	-.2090	-.3100	-.4100	-.4820	-.5500	-.5500
52.5	-.0380	-.0730	-.1220	-.1630	-.2160	-.3190	-.4230	-.4900	-.5550	-.5550
55.0	-.0400	-.0790	-.1270	-.1710	-.2220	-.3280	-.4320	-.4990	-.5620	-.5620
57.5	-.0420	-.0820	-.1320	-.1780	-.2300	-.3360	-.4420	-.5080	-.5700	-.5700
60.0	-.0440	-.0880	-.1380	-.1830	-.2380	-.3420	-.4490	-.5170	-.5780	-.5780
62.5	-.0470	-.0920	-.1420	-.1910	-.2430	-.3490	-.4540	-.5220	-.5870	-.5870
65.0	-.0490	-.0980	-.1470	-.1970	-.2490	-.3550	-.4590	-.5290	-.5960	-.5960
67.5	-.0500	-.1010	-.1500	-.2010	-.2520	-.3590	-.4620	-.5330	-.6020	-.6020
70.0	-.0500	-.1040	-.1520	-.2030	-.2560	-.3620	-.4650	-.5380	-.6080	-.6080
72.5	-.0500	-.1080	-.1550	-.2040	-.2580	-.3630	-.4680	-.5390	-.6100	-.6100
75.0	-.0500	-.1100	-.1580	-.2050	-.2580	-.3630	-.4680	-.5410	-.6110	-.6110
77.5	-.0480	-.1110	-.1590	-.2040	-.2570	-.3620	-.4670	-.5410	-.6120	-.6120
80.0	-.0470	-.1120	-.1600	-.2020	-.2540	-.3610	-.4650	-.5400	-.6120	-.6120
82.5	-.0450	-.1120	-.1600	-.2000	-.2510	-.3580	-.4620	-.5380	-.6110	-.6110
85.0	-.0420	-.1120	-.1600	-.1980	-.2490	-.3530	-.4590	-.5360	-.6090	-.6090
87.5	-.0400	-.1120	-.1580	-.1930	-.2430	-.3490	-.4530	-.5320	-.6070	-.6070
90.0	-.0380	-.1120	-.1550	-.1860	-.2360	-.3420	-.4480	-.5260	-.6010	-.6010

DE= -15.0

BETA / ALPHA	2.0	4.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	90.0
0.	-.0270	-.0520	-.0820	-.1030	-.1400	-.2710	-.3800	-.4400	-.5060	-.5060
2.5	-.0280	-.0530	-.0830	-.1100	-.1390	-.2890	-.4000	-.4660	-.5280	-.5280
5.0	-.0290	-.0540	-.0850	-.1120	-.1420	-.3030	-.4160	-.4810	-.5470	-.5470
7.5	-.0300	-.0570	-.0830	-.1160	-.1480	-.3110	-.4210	-.4900	-.5590	-.5590
10.0	-.0320	-.0590	-.0930	-.1220	-.1540	-.3100	-.4200	-.4900	-.5610	-.5610
12.5	-.0320	-.0630	-.0990	-.1310	-.1670	-.3020	-.4080	-.4770	-.5450	-.5450
15.0	-.0350	-.0690	-.1050	-.1400	-.1780	-.2880	-.3840	-.4500	-.5200	-.5200
17.5	-.0360	-.0710	-.1050	-.1390	-.1800	-.2720	-.3580	-.4160	-.4890	-.4890
20.0	-.0370	-.0690	-.1030	-.1320	-.1720	-.2570	-.3350	-.3930	-.4540	-.4540
22.5	-.0370	-.0680	-.1000	-.1300	-.1700	-.2500	-.3230	-.3760	-.4260	-.4260
25.0	-.0340	-.0680	-.0980	-.1270	-.1700	-.2440	-.3190	-.3700	-.4210	-.4210
27.5	-.0330	-.0680	-.0970	-.1220	-.1600	-.2400	-.3160	-.3690	-.4270	-.4270
30.0	-.0330	-.0690	-.0980	-.1220	-.1600	-.2400	-.3190	-.3750	-.4400	-.4400
32.5	-.0330	-.0700	-.0990	-.1230	-.1620	-.2430	-.3220	-.3860	-.4550	-.4550
35.0	-.0320	-.0700	-.1010	-.1270	-.1670	-.2500	-.3300	-.4010	-.4730	-.4730
37.5	-.0320	-.0700	-.1020	-.1310	-.1690	-.2560	-.3380	-.4190	-.4980	-.4980
40.0	-.0320	-.0710	-.1050	-.1370	-.1750	-.2640	-.3490	-.4360	-.5200	-.5200
42.5	-.0320	-.0700	-.1110	-.1430	-.1830	-.2770	-.3640	-.4510	-.5370	-.5370
45.0	-.0320	-.0700	-.1180	-.1510	-.1940	-.2900	-.3810	-.4640	-.5480	-.5480
47.5	-.0320	-.0700	-.1190	-.1560	-.2020	-.3010	-.3960	-.4740	-.5500	-.5500
50.0	-.0360	-.0710	-.1200	-.1600	-.2090	-.3100	-.4100	-.4820	-.5500	-.5500
52.5	-.0380	-.0730	-.1220	-.1630	-.2160	-.3190	-.4230	-.4900	-.5550	-.5550
55.0	-.0400	-.0790	-.1270	-.1710	-.2220	-.3280	-.4320	-.4990	-.5620	-.5620
57.5	-.0420	-.0820	-.1320	-.1780	-.2300	-.3360	-.4420	-.5080	-.5700	-.5700
60.0	-.0440	-.0830	-.1380	-.1830	-.2380	-.3420	-.4490	-.5170	-.5780	-.5780
62.5	-.0470	-.0920	-.1420	-.1910	-.2430	-.3490	-.4540	-.5220	-.5870	-.5870
65.0	-.0490	-.0980	-.1470	-.1970	-.2490	-.3550	-.4590	-.5290	-.5960	-.5960
67.5	-.0500	-.1010	-.1500	-.2010	-.2520	-.3590	-.4620	-.5330	-.6020	-.6020
70.0	-.0500	-.1040	-.1520	-.2030	-.2560	-.3620	-.4650	-.5380	-.6080	-.6080
72.5	-.0500	-.1080	-.1550	-.2040	-.2580	-.3630	-.4680	-.5390	-.6100	-.6100
75.0	-.0500	-.1100	-.1580	-.2050	-.2580	-.3630	-.4680	-.5410	-.6110	-.6110
77.5	-.0480	-.1110	-.1590	-.2040	-.2570	-.3620	-.4670	-.5410	-.6120	-.6120
80.0	-.0470	-.1120	-.1600	-.2020	-.2540	-.3610	-.4650	-.5400	-.6120	-.6120
82.5	-.0450	-.1120	-.1600	-.2000	-.2510	-.3580	-.4620	-.5380	-.6110	-.6110
85.0	-.0420	-.1120	-.1600	-.1980	-.2490	-.3530	-.4590	-.5360	-.6090	-.6090

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 87.5-.0400-.1120-.1580-.1930-.2430-.3490-.4530-.5320-.6070-.6070
 90.0-.0380-.1120-.1550-.1860-.2360-.3420-.4480-.5260-.6010-.6010
          DE=  -5.0
BETA    2.0    4.0    6.0    8.0   10.0   15.0   20.0   25.0   30.0   90.0
 _PHA
  0. -.0270-.0520-.0820-.1090-.1400-.2710-.3800-.4400-.5060-.5060
  2.5-.0280-.0530-.0830-.1100-.1390-.2890-.4000-.4660-.5280-.5280
  5.0-.0290-.0540-.0850-.1120-.1420-.3030-.4160-.4810-.5470-.5470
  7.5-.0300-.0570-.0880-.1160-.1480-.3160-.4280-.4940-.5620-.5620
 10.0-.0320-.0590-.0930-.1220-.1540-.3210-.4390-.5030-.5680-.5680
 12.5-.0320-.0630-.0990-.1310-.1630-.3210-.4350-.4950-.5570-.5570
 15.0-.0350-.0690-.1050-.1460-.1800-.3090-.4190-.4710-.5330-.5330
 17.5-.0360-.0710-.1100-.1470-.1890-.2900-.3950-.4470-.5030-.5030
 20.0-.0370-.0690-.1100-.1420-.1840-.2760-.3660-.4200-.4720-.4720
 22.5-.0370-.0680-.1100-.1400-.1800-.2670-.3470-.4000-.4480-.4480
 25.0-.0340-.0680-.1080-.1390-.1730-.2600-.3400-.3910-.4380-.4380
 27.5-.0330-.0680-.1040-.1380-.1700-.2570-.3370-.3910-.4400-.4400
 30.0-.0330-.0690-.1050-.1380-.1700-.2560-.3380-.3980-.4510-.4510
 32.5-.0330-.0700-.1110-.1380-.1700-.2580-.3400-.4050-.4680-.4680
 35.0-.0320-.0700-.1130-.1390-.1720-.2600-.3420-.4180-.4860-.4860
 37.5-.0320-.0700-.1130-.1400-.1770-.2630-.3500-.4290-.5040-.5040
 40.0-.0320-.0710-.1130-.1420-.1810-.2710-.3580-.4420-.5220-.5220
 42.5-.0320-.0700-.1160-.1470-.1880-.2800-.3690-.4540-.5370-.5370
 45.0-.0320-.0700-.1180-.1510-.1940-.2900-.3810-.4640-.5480-.5480
 47.5-.0320-.0700-.1190-.1560-.2020-.3010-.3960-.4740-.5500-.5500
 50.0-.0360-.0710-.1200-.1600-.2090-.3100-.4100-.4820-.5500-.5500
 52.5-.0380-.0730-.1220-.1630-.2160-.3190-.4230-.4900-.5550-.5550
 55.0-.0400-.0790-.1270-.1710-.2220-.3280-.4320-.4990-.5620-.5620
 57.5-.0420-.0820-.1320-.1780-.2300-.3360-.4420-.5080-.5700-.5700
 60.0-.0440-.0880-.1380-.1830-.2380-.3420-.4490-.5170-.5780-.5780
 62.5-.0470-.0920-.1420-.1910-.2430-.3490-.4540-.5220-.5870-.5870
 65.0-.0490-.0980-.1470-.1970-.2490-.3550-.4590-.5290-.5960-.5960
 67.5-.0500-.1010-.1500-.2010-.2520-.3590-.4620-.5330-.6020-.6020
 70.0-.0500-.1040-.1520-.2030-.2560-.3620-.4650-.5380-.6080-.6080
 72.5-.0500-.1080-.1550-.2040-.2580-.3630-.4680-.5390-.6100-.6100
 75.0-.0500-.1100-.1580-.2050-.2580-.3630-.4680-.5410-.6110-.6110
 77.5-.0480-.1110-.1590-.2040-.2570-.3620-.4670-.5410-.6120-.6120
 80.0-.0470-.1120-.1600-.2020-.2540-.3610-.4650-.5400-.6120-.6120
 82.5-.0450-.1120-.1600-.2000-.2510-.3580-.4620-.5380-.6110-.6110
 85.0-.0420-.1120-.1600-.1980-.2490-.3530-.4590-.5360-.6090-.6090
 87.5-.0400-.1120-.1580-.1930-.2430-.3490-.4530-.5320-.6070-.6070
 90.0-.0380-.1120-.1550-.1860-.2360-.3420-.4480-.5260-.6010-.6010
 STOP
```

CL(ALPHA,DE) LIFT COEFF. IN STABILITY COORD.

DE / ALPHA	-25.0	-20.0	-15.0	-5.0
0.	-.3600	-.3000	-.2450	-.1400
2.5	-.1625	-.1100	-.0500	.0500
5.0	.0200	.0800	.1300	.2500
7.5	.2100	.2700	.3200	.4300
10.0	.3900	.4450	.5000	.6000
12.5	.5600	.6200	.6600	.7800
15.0	.7100	.7500	.8100	.9000
17.5	.8400	.9000	.9500	1.0300
20.0	.9400	1.0100	1.0600	1.1600
22.5	1.0200	1.0800	1.1400	1.2200
25.0	1.0600	1.1400	1.1900	1.2600
27.5	1.0800	1.1600	1.2150	1.2800
30.0	1.0900	1.1600	1.2150	1.2800
32.5	1.0900	1.1600	1.2150	1.2700
35.0	1.0800	1.1600	1.2100	1.2600
37.5	1.0800	1.1600	1.2000	1.2500
40.0	1.0700	1.1500	1.1900	1.2300
42.5	1.0600	1.1400	1.1800	1.2100
45.0	1.0550	1.1300	1.1600	1.1900
47.5	1.0500	1.1200	1.1400	1.1600
50.0	1.0350	1.0950	1.1100	1.1400
52.5	1.0200	1.0700	1.0800	1.0800
55.0	.9800	1.0200	1.0450	1.0450
57.5	.9400	.9800	.9900	.9900
60.0	.9000	.9200	.9400	.9400
62.5	.8500	.8600	.8700	.8700
65.0	.7900	.8100	.8100	.8100
67.5	.7400	.7400	.7400	.7400
70.0	.6800	.6800	.6800	.6800
72.5	.6200	.6200	.6200	.6200
75.0	.5600	.5600	.5600	.5600
77.5	.4900	.4900	.4900	.4900
80.0	.4300	.4300	.4300	.4300
82.5	.3500	.3500	.3500	.3500
85.0	.2800	.2800	.2800	.2800
87.5	.2000	.2000	.2000	.2000
90.0	.1350	.1350	.1350	.1350

CM(ALPHA,DE)

DE / ALPHA	-25.0	-20.0	-15.0	-5.0
0.	.3800	.3000	.2200	.0550
2.5	.3600	.2800	.2000	.0400
5.0	.3400	.2600	.1800	.0280
7.5	.3200	.2400	.1600	0.
10.0	.3050	.2200	.1400	-.0300
12.5	.2800	.2000	.1200	-.0500
15.0	.2400	.1700	.0900	-.0550
17.5	.2100	.1400	.0700	-.0800
20.0	.1750	.1030	.0250	-.1300
22.5	.1300	.0550	-.0300	-.1800
25.0	.0600	0.	-.0850	-.2500
27.5	-.0200	-.0700	-.1500	-.3100
30.0	-.0900	-.1400	-.2100	-.3600
32.5	-.1600	-.2100	-.2700	-.4000
35.0	-.2300	-.2700	-.3200	-.4200
37.5	-.3000	-.3400	-.3700	-.4450
40.0	-.3800	-.4000	-.4200	-.4700
42.5	-.4400	-.4450	-.4700	-.4950
45.0	-.4850	-.4850	-.5100	-.5200
47.5	-.5400	-.5400	-.5400	-.5400
50.0	-.5700	-.5700	-.5700	-.5700
52.5	-.6100	-.6100	-.6100	-.6100
55.0	-.6300	-.6300	-.6300	-.6300
57.5	-.6600	-.6600	-.6600	-.6600
60.0	-.6800	-.6800	-.6800	-.6800
62.5	-.7000	-.7000	-.7000	-.7000
65.0	-.7200	-.7200	-.7200	-.7200
67.5	-.7400	-.7400	-.7400	-.7400
70.0	-.7500	-.7500	-.7500	-.7500
72.5	-.7650	-.7650	-.7650	-.7650
75.0	-.7900	-.7900	-.7900	-.7900
77.5	-.8050	-.8050	-.8050	-.8050
80.0	-.8200	-.8200	-.8200	-.8200
82.5	-.8300	-.8300	-.8300	-.8300
85.0	-.8450	-.8450	-.8450	-.8450
87.5	-.8500	-.8500	-.8500	-.8500
90.0	-.8600	-.8600	-.8600	-.8600

CD(ALPHA,DE)

DE / ALPHA	-25.0	-20.0	-15.0	-5.0
0.	.0800	.0400	.0200	0.
2.5	.0750	.0450	.0250	.0200
5.0	.0600	.0450	.0300	.0300
7.5	.0800	.0450	.0400	.0400
10.0	.1250	.0550	.0550	.0550
12.5	.1650	.1100	.1100	.1100
15.0	.2400	.1600	.1600	.1600
17.5	.3100	.1900	.2400	.2400
20.0	.3700	.2700	.3200	.3200
22.5	.4500	.3900	.3900	.4100
25.0	.5200	.4500	.4700	.5000
27.5	.5800	.5400	.5500	.5700
30.0	.6500	.6000	.6200	.6500
32.5	.7300	.6700	.7000	.7350
35.0	.8000	.7500	.7800	.8100
37.5	.8800	.8300	.8600	.8900
40.0	.9600	.9100	.9350	.9600
42.5	1.0400	1.0000	1.0100	1.0500
45.0	1.1300	1.0700	1.1000	1.1350
47.5	1.2400	1.1600	1.1700	1.2200
50.0	1.3200	1.2400	1.2500	1.2950
52.5	1.3800	1.3200	1.3200	1.3700
55.0	1.4300	1.3800	1.3800	1.4100
57.5	1.4800	1.4300	1.4300	1.4600
60.0	1.5200	1.4800	1.4800	1.5000
62.5	1.5600	1.5200	1.5200	1.5400
65.0	1.5900	1.5600	1.5600	1.5600
67.5	1.6200	1.5900	1.5900	1.5900
70.0	1.6500	1.6200	1.6200	1.6200
72.5	1.6700	1.6500	1.6500	1.6500
75.0	1.7000	1.6700	1.6700	1.6700
77.5	1.7100	1.7000	1.7000	1.7000
80.0	1.7300	1.7100	1.7100	1.7100
82.5	1.7900	1.7300	1.7300	1.7300
85.0	1.8000	1.7900	1.7900	1.7900
87.5	1.8000	1.8000	1.8000	1.8000
90.0	1.8000	1.8000	1.8000	1.8000

CMQ(ALPHA,DE)

DE / ALPHA	-25.0	-20.0	-15.0	-5.0
0.	-3.6200	-4.7600	-5.5000	-5.7300
2.5	-4.1300	-5.1700	-5.7800	-5.7000
5.0	-4.2000	-5.3900	-6.0100	-5.6400
7.5	-4.2200	-5.4500	-6.0800	-5.5600
10.0	-4.3500	-5.3800	-5.8900	-5.4800
12.5	-4.5300	-5.2300	-5.6300	-5.4100
15.0	-4.8200	-5.1900	-5.4000	-5.3900
17.5	-5.2000	-5.2000	-5.2500	-5.4900
20.0	-5.5900	-5.2700	-5.1900	-5.6800
22.5	-5.5000	-5.2200	-5.1100	-5.2800
25.0	-5.0400	-5.2100	-5.1800	-4.4300
27.5	-4.8200	-5.1600	-5.1000	-3.7300
30.0	-4.7700	-4.8300	-4.5900	-3.2000
32.5	-4.9000	-4.4800	-3.9700	-2.6400
35.0	-4.9500	-4.1000	-3.3500	-2.2300
37.5	-4.5200	-3.6200	-2.9200	-2.2400
40.0	-3.9800	-3.2000	-2.6900	-2.3700
42.5	-3.4000	-2.9000	-2.5900	-2.4500
45.0	-2.9100	-2.7100	-2.5900	-2.5600
47.5	-2.7200	-2.6500	-2.6100	-2.6700
50.0	-2.6600	-2.6400	-2.6600	-2.8000
52.5	-2.6000	-2.6800	-2.7300	-2.9200
55.0	-2.6300	-2.7500	-2.8600	-3.0700
57.5	-2.7200	-2.8600	-3.0000	-3.2000
60.0	-2.8700	-3.0200	-3.1500	-3.3300
62.5	-3.0300	-3.2000	-3.3200	-3.4800
65.0	-3.2000	-3.3600	-3.4800	-3.6200
67.5	-3.3800	-3.5200	-3.6300	-3.7700
70.0	-3.5100	-3.6800	-3.7800	-3.9100
72.5	-3.6300	-3.8000	-3.9200	-4.0400
75.0	-3.7700	-3.9200	-4.0600	-4.1800
77.5	-3.9000	-4.0600	-4.1900	-4.3100
80.0	-4.0200	-4.1900	-4.3200	-4.4400
82.5	-4.1700	-4.3200	-4.4300	-4.5800
85.0	-4.3100	-4.4600	-4.5800	-4.7100
87.5	-4.4600	-4.6000	-4.7200	-4.8300
90.0	-4.6100	-4.7300	-4.8300	-5.0000

CMAD(ALPHA,DE) [$C_{M\dot{\alpha}}$]

DE / ALPHA	-25.0	-20.0	-15.0	-5.0
0.	-.4200	-.9600	-1.2800	-1.4000
2.5	-.6300	-1.0700	-1.3400	-1.3700
5.0	-.6800	-1.1800	-1.4700	-1.3000
7.5	-.6800	-1.1700	-1.4300	-1.2200
10.0	-.6800	-1.0800	-1.3000	-1.1200
12.5	-.7100	-.9800	-1.1200	-1.0000
15.0	-.7000	-.7700	-.8100	-.8700
17.5	-.6100	-.6700	-.6800	-.6900
20.0	.1900	.1900	.1900	.1900
22.5	1.2100	1.1300	1.1000	1.1300
25.0	1.4200	1.5000	1.5000	1.1100
27.5	1.5900	1.7700	1.7000	.9300
30.0	1.5000	1.5600	1.4000	.5500
32.5	.8200	.8500	.7200	.2600
35.0	.1200	.1900	.0900	0.
37.5	.0200	0.	-.0200	-.0200
40.0	0.	0.	0.	0.
42.5	0.	0.	0.	0.
45.0	0.	0.	0.	0.
47.5	0.	0.	0.	0.
50.0	0.	0.	0.	0.
52.5	0.	0.	0.	0.
55.0	0.	0.	0.	0.
57.5	0.	0.	0.	0.
60.0	0.	0.	0.	0.
62.5	0.	0.	0.	0.
65.0	0.	0.	0.	0.
67.5	0.	0.	0.	0.
70.0	0.	0.	0.	0.
72.5	0.	0.	0.	0.
75.0	0.	0.	0.	0.
77.5	0.	0.	0.	0.
80.0	0.	0.	0.	0.
82.5	0.	0.	0.	0.
85.0	0.	0.	0.	0.
87.5	0.	0.	0.	0.
90.0	0.	0.	0.	0.

BODY COORDINATES

ALPHA	CLP	CLR	CNP	CNR
0.	-.313	.030	.060	-.294
2.5	-.316	.055	.019	-.291
5.0	-.319	.080	-.017	-.288
7.5	-.322	.104	-.040	-.288
10.0	-.328	.124	-.042	-.280
12.5	-.339	.128	-.018	-.258
15.0	-.319	.122	.020	-.232
17.5	-.271	.111	.064	-.205
20.0	-.230	.101	.104	-.177
22.5	-.156	.126	.069	-.183
25.0	-.103	.142	.082	-.164
27.5	-.093	.143	.088	-.142
30.0	-.102	.132	.073	-.117
32.5	-.102	.121	.062	-.089
35.0	-.101	.107	.049	-.062
37.5	-.096	.093	.035	-.038
40.0	-.093	.082	.023	-.021
42.5	-.090	.079	.017	-.016
45.0	-.091	.079	.014	-.014
47.5	-.093	.081	.011	-.015
50.0	-.098	.085	.009	-.016
52.5	-.109	.091	.006	-.015
55.0	-.127	.100	.004	-.012
57.5	-.148	.106	-.001	-.007
60.0	-.172	.111	-.008	.001
62.5	-.195	.115	-.015	.007
65.0	-.215	.113	-.025	.016
67.5	-.228	.106	-.035	.026
70.0	-.231	.094	-.045	.034
72.5	-.227	.080	-.053	.042
75.0	-.216	.065	-.058	.050
77.5	-.198	.050	-.061	.056
80.0	-.176	.036	-.059	.062
82.5	-.149	.023	-.054	.070
85.0	-.117	.012	-.042	.075
87.5	-.088	.005	-.027	.083
90.0	-.046	-.000	-.004	.091

CL(ALPHA,DA) ROLL COEFF., RIGHT SIDE DA ONLY, BODY COORD.

DA / ALPHA	-25.	-20.	-15.	-10.	-5.	0.	5.	10.	15.	20.	25.
0.	.0232	.0200	.0160	.0130	.0058	0.	-.0057	-.0110	-.0157	-.0198	-.0230
2.	.0230	.0198	.0159	.0129	.0058	0.	-.0057	-.0110	-.0157	-.0198	-.0230
4.	.0228	.0197	.0156	.0129	.0057	0.	-.0057	-.0109	-.0156	-.0197	-.0230
6.	.0226	.0196	.0153	.0108	.0055	0.	-.0053	-.0106	-.0153	-.0194	-.0227
10.	.0207	.0178	.0140	.0098	.0051	0.	-.0050	-.0096	-.0142	-.0171	-.0219
14.	.0182	.0150	.0118	.0083	.0042	0.	-.0041	-.0081	-.0122	-.0155	-.0193
16.	.0205	.0167	.0128	.0087	.0045	0.	-.0041	-.0080	-.0123	-.0166	-.0203
18.	.0193	.0164	.0124	.0085	.0044	0.	-.0038	-.0077	-.0115	-.0154	-.0191
20.	.0189	.0157	.0123	.0085	.0043	0.	-.0036	-.0072	-.0108	-.0142	-.0177
22.	.0174	.0148	.0114	.0080	.0041	0.	-.0033	-.0064	-.0095	-.0125	-.0154
24.	.0164	.0138	.0108	.0075	.0038	0.	-.0030	-.0056	-.0082	-.0108	-.0133
26.	.0097	.0078	.0058	.0039	.0018	0.	-.0012	-.0024	-.0040	-.0059	-.0083
30.	.0003	.0004	.0003	.0005	.0000	0.	.0002	.0002	.0002	-.0001	-.0006
35.	.0005	.0006	.0004	.0004	.0001	0.	.0002	.0001	-.0000	-.0004	-.0009
40.	.0027	.0026	.0023	.0019	.0011	0.	-.0007	-.0014	-.0023	-.0032	-.0045
45.	.0052	.0043	.0035	.0023	.0013	0.	-.0009	-.0016	-.0028	-.0040	-.0052
50.	.0038	.0033	.0027	.0018	.0011	0.	-.0008	-.0013	-.0023	-.0033	-.0042
90.	.0016	.0020	.0020	.0015	.0009	0.	-.0008	-.0013	-.0021	-.0029	-.0038

CN(ALPHA,DA) YAW COEFF., RIGHT SIDE ONLY, BODY COORD.

DA / ALPHA	-25.	-20.	-15.	-10.	-5.	0.	5.	10.	15.	20.	25.
0.	.0066	.0049	.0033	.0021	.0009	0.	-.0007	-.0011	-.0140	-.0015	-.0014
2.	.0066	.0049	.0036	.0022	.0010	0.	-.0008	-.0012	-.0014	-.0016	-.0014
4.	.0066	.0050	.0036	.0022	.0011	0.	-.0008	-.0013	-.0015	-.0016	-.0013
6.	.0066	.0051	.0035	.0021	.0012	0.	-.0008	-.0013	-.0016	-.0015	-.0013
10.	.0064	.0049	.0034	.0022	.0012	0.	-.0007	-.0012	-.0014	-.0012	-.0010
14.	.0057	.0043	.0030	.0018	.0007	0.	-.0005	-.0008	-.0009	-.0006	-.0002
16.	.0047	.0039	.0032	.0022	.0010	0.	-.0002	-.0002	-.0004	-.0003	.0000
18.	.0040	.0030	.0022	.0015	.0007	0.	-.0002	-.0003	-.0005	-.0004	-.0001
20.	.0035	.0020	.0011	.0004	.0002	0.	-.0001	-.0003	-.0004	-.0003	-.0001
22.	.0036	.0022	.0012	.0005	.0003	0.	-.0001	-.0002	-.0003	-.0001	.0002
24.	.0038	.0023	.0013	.0006	.0003	0.	-.0001	-.0001	-.0000	.0002	.0006
26.	.0012	-.0001	-.0007	-.0009	-.0006	0.	.0006	.0013	.0017	.0022	.0026
30.	-.0035	-.0038	-.0035	-.0026	-.0015	0.	.0014	.0025	.0039	.0051	.0066
35.	-.0033	-.0035	-.0034	-.0027	-.0015	0.	.0013	.0024	.0037	.0050	.0062
40.	-.0012	-.0016	-.0015	-.0013	-.0007	0.	.0006	.0010	.0015	.0021	.0024
45.	.0023	.0009	.0003	-.0000	-.0000	0.	.0002	.0002	.0002	.0001	.0002
50.	.0025	.0013	.0006	.0002	.0001	0.	.0000	-.0002	-.0004	-.0008	-.0010
90.	-.0007	-.0008	-.0007	-.0005	-.0002	0.	.0003	.0005	.0005	.0006	.0006

CM(ALPHA,DA) RIGHT SIDE DA ONLY

ALPHA DA	0.	2.0	4.0	6.0	10.0	14.0	16.0	90.0
-25.0	.0340	.0333	.0320	.0292	.0220	.0110	0.	0.
-20.0	.0320	.0317	.0315	.0290	.0235	.0137	0.	0.
-15.0	.0268	.0268	.0260	.0260	.0212	.0132	0.	0.
-10.0	.0200	.0200	.0190	.0190	.0160	.0107	0.	0.
-5.0	.0105	.0105	.0105	.0105	.0090	.0060	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
5.0	-.0105	-.0105	-.0105	-.0105	-.0090	-.0060	0.	0.
10.0	-.0217	-.0217	-.0217	-.0217	-.0184	-.0127	0.	0.
15.0	-.0330	-.0330	-.0320	-.0320	-.0270	-.0190	0.	0.
20.0	-.0420	-.0420	-.0420	-.0400	-.0343	-.0242	0.	0.
25.0	-.0507	-.0507	-.0490	-.0470	-.0394	-.0280	0.	0.

CY(ALPHA,DA) RIGHT SIDE DA ONLY

ALPHA DA	0.	2.0	4.0	6.0	10.0	14.0	16.0	90.0
-25.0	-.0115	-.0106	-.0097	-.0088	-.0070	-.0051	0.	0.
25.0	.0115	.0106	.0097	.0088	.0070	.0051	0.	0.

SPOILER COEFF., RIGHT SIDE ONLY

ALPHA COEFF	DS	0.	2.0	4.0	6.0	10.0	14.0	16.0	90.0
CL	0.	0.	0.	0.	0.	0.	0.	0.	0.
CL	60.	-.0365	-.0392	-.0406	-.0409	-.0381	-.0309	0.	0.
CD	0.	0.	0.	0.	0.	0.	0.	0.	0.
CD	60.	.0009	-.0003	-.0015	-.0027	-.0050	-.0071	0.	0.
CM	0.	0.	0.	0.	0.	0.	0.	0.	0.
CM	60.	-.0078	-.0089	-.0096	-.0099	-.0091	-.0066	0.	0.
CY	0.	0.	0.	0.	0.	0.	0.	0.	0.
CY	60.	-.0054	-.0051	-.0047	-.0044	-.0037	-.0031	0.	0.

CL(ALPHA,DS) ROLL COEFF., RT. SIDE ONLY, BODY COORD

DS / ALPHA	0.	10.0	20.0	30.0	40.0	50.0	60.0
0.	0.	.00094	.00190	.00282	.00373	.00468	.00560
2.	0.	.00103	.00207	.00310	.00412	.00513	.00621
4.	0.	.00112	.00219	.00327	.00434	.00541	.00651
6.	0.	.00111	.00223	.00334	.00443	.00553	.00663
10.	0.	.00110	.00215	.00321	.00426	.00526	.00631
14.	0.	.00090	.00173	.00261	.00345	.00433	.00520
16.	0.	.00061	.00124	.00192	.00308	.00421	.00582
18.	0.	.00046	.00098	.00154	.00222	.00295	.00416
20.	0.	.00038	.00077	.00129	.00165	.00206	.00258
22.	0.	.00037	.00063	.00103	.00144	.00187	.00232
24.	0.	.00024	.00058	.00086	.00132	.00179	.00211
26.	0.	.00004	.00013	.00026	.00053	.00060	.00044
30.	0.	-.00118	-.00210	-.00275	-.00194	-.00136	-.00070
35.	0.	-.00136	-.00228	-.00275	-.00209	-.00149	-.00081
40.	0.	.00007	.00023	.00049	.00113	.00100	.00068
45.	0.	.00014	.00036	.00068	.00124	.00117	.00085
50.	0.	.00005	.00016	.00031	.00058	.00080	.00069
70.	0.	-.00043	-.00075	-.00094	-.00091	-.00063	-.00021
90.	0.	.00009	.00026	.00050	.00101	.00114	.00096

CN(ALPHA,DS) YAW COEFF., RT. SIDE ONLY, BODY COORD.

DS / ALPHA	0.	10.0	20.0	30.0	40.0	50.0	60.0
0.	0.	.00047	.00094	.00141	.00189	.00236	.00282
2.	0.	.00044	.00089	.00136	.00180	.00225	.00270
4.	0.	.00044	.00087	.00129	.00173	.00216	.00259
6.	0.	.00041	.00083	.00125	.00165	.00208	.00250
10.	0.	.00038	.00075	.00111	.00148	.00184	.00222
14.	0.	.00030	.00057	.00085	.00112	.00146	.00169
16.	0.	.00025	.00046	.00063	.00088	.00110	.00147
18.	0.	.00019	.00037	.00054	.00067	.00080	.00112
20.	0.	.00016	.00028	.00041	.00049	.00054	.00067
22.	0.	.00011	.00015	.00020	.00020	.00022	.00040
24.	0.	.00007	.00012	.00003	-.00018	-.00022	.00006
26.	0.	-.00009	-.00027	-.00054	-.00108	-.00122	-.00090
30.	0.	-.00091	-.00180	-.00264	-.00362	-.00298	-.00178
35.	0.	-.00113	-.00215	-.00304	-.00399	-.00324	-.00197
40.	0.	-.00008	-.00028	-.00058	-.00135	-.00120	-.00081
45.	0.	.00001	-.00008	-.00025	-.00082	-.00076	-.00057
50.	0.	-.00004	-.00013	-.00026	-.00049	-.00067	-.00058
70.	0.	-.00117	-.00207	-.00274	-.00276	-.00219	-.00131
90.	0.	-.00093	-.00160	-.00200	-.00200	-.00138	-.00065

RUDDER COEFFICIENTS

COORD. ALPHA	CYDR	BODY CLDR	BODY CNDR
0.	.00440	.00006	-.00199
5.0	.00440	.00022	-.00198
10.0	.00440	.00036	-.00196
15.0	.00435	.00052	-.00192
20.0	.00400	.00065	-.00179
25.0	.00350	.00073	-.00167
30.0	.00300	.00061	-.00124
35.0	.00240	.00037	-.00082
40.0	.00190	.00012	-.00053
45.0	.00170	-.00003	-.00045
50.0	.00180	.00002	-.00059
55.0	.00180	.00010	-.00070
60.0	.00168	.00022	-.00078
65.0	.00150	.00033	-.00080
70.0	.00130	.00042	-.00073
75.0	.00108	.00043	-.00060
80.0	.00091	.00039	-.00042
85.0	.00052	.00028	-.00022
90.0	.00020	.00010	-.00000

STOP

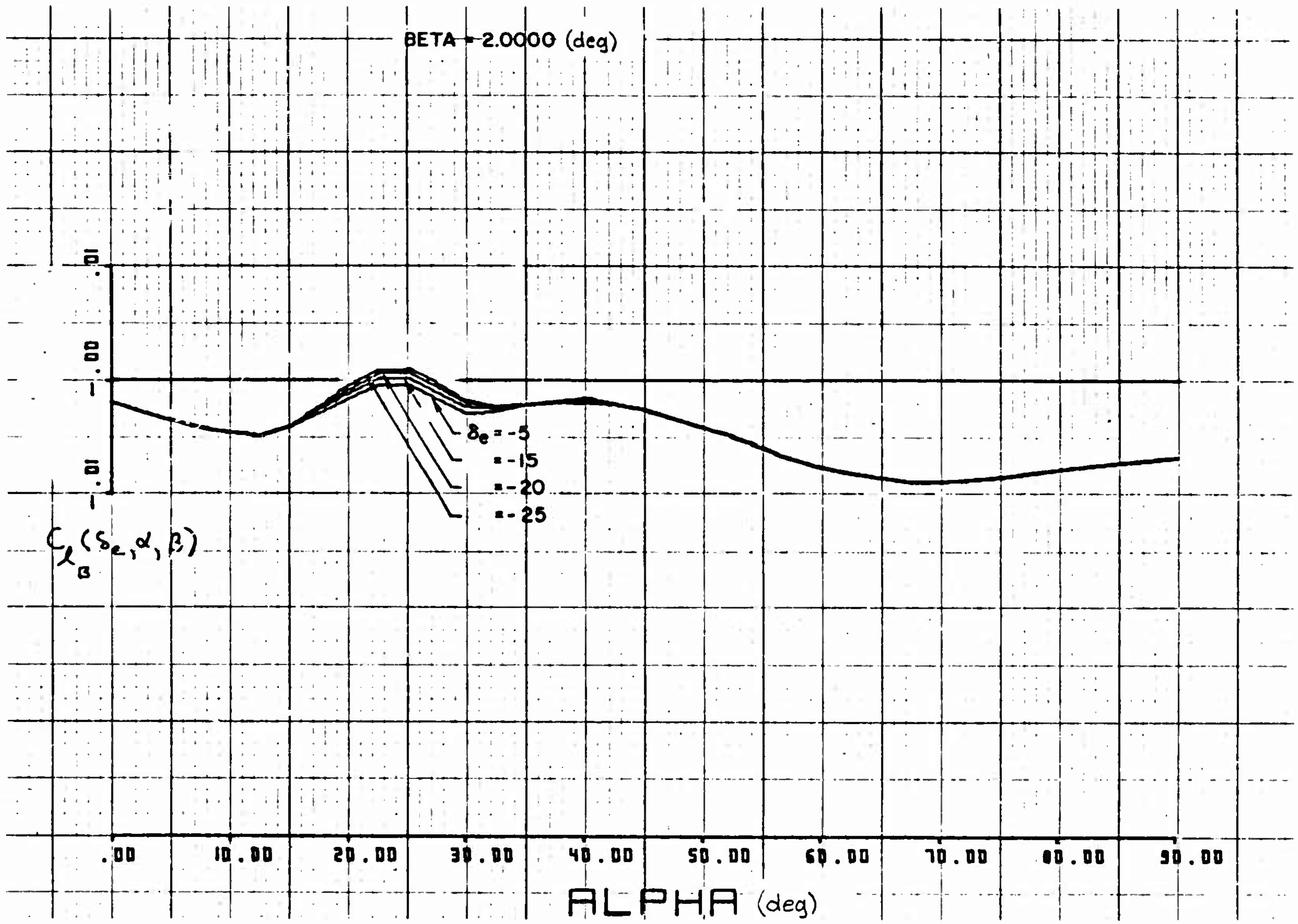


Figure 2. $C_{\ell_B}(\delta_e, \alpha, \beta)$

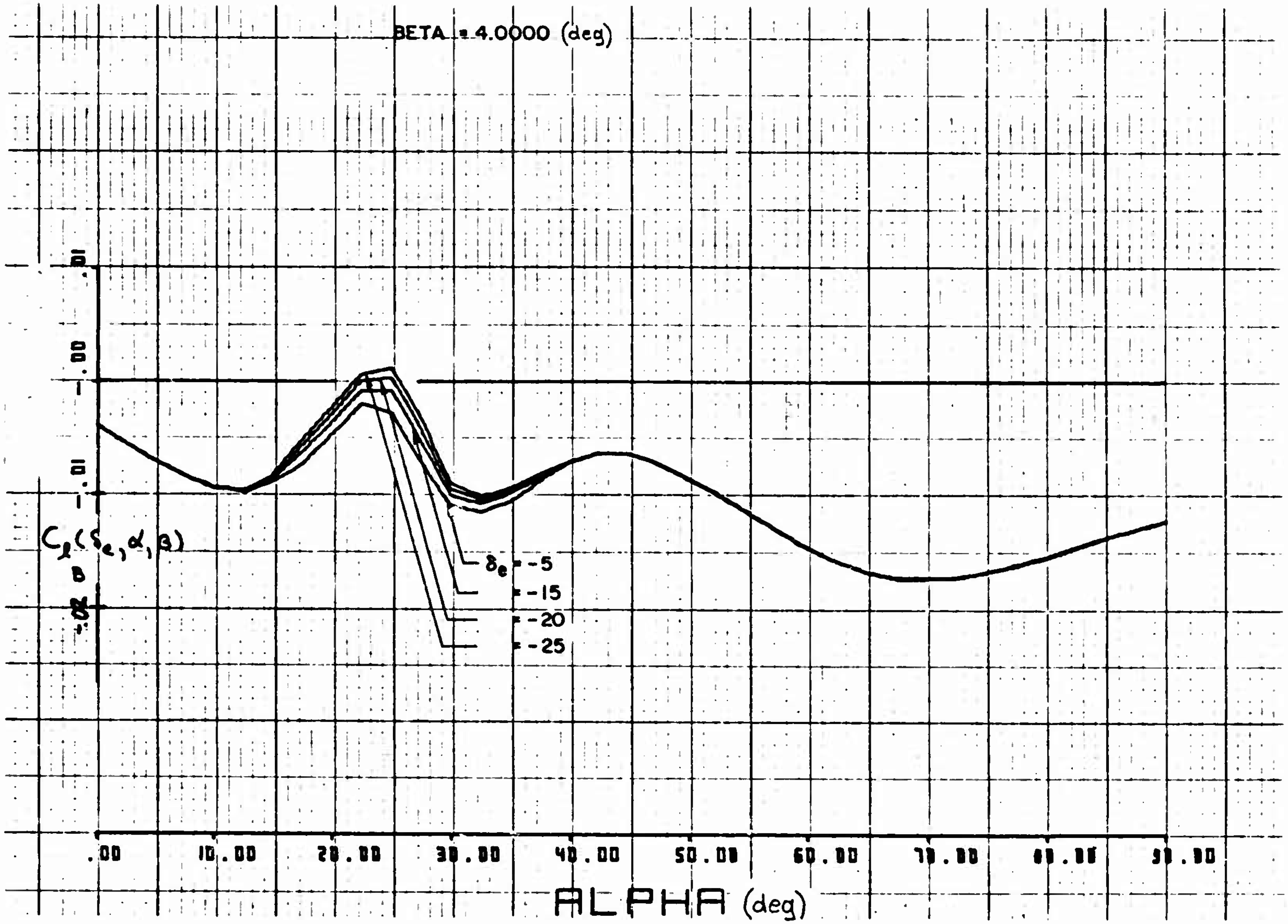


Figure 2. (Continued)

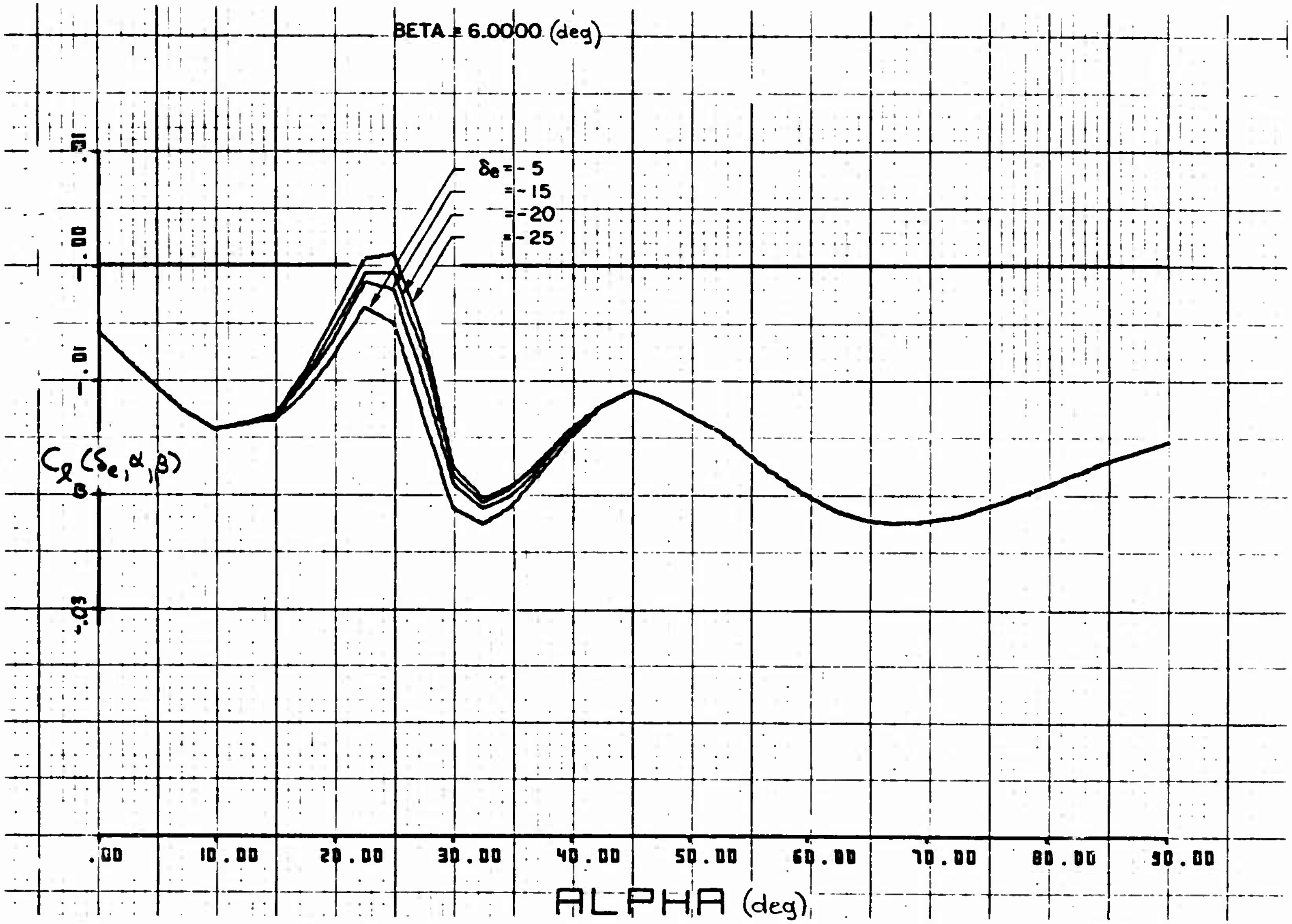


Figure 2. (Continued)

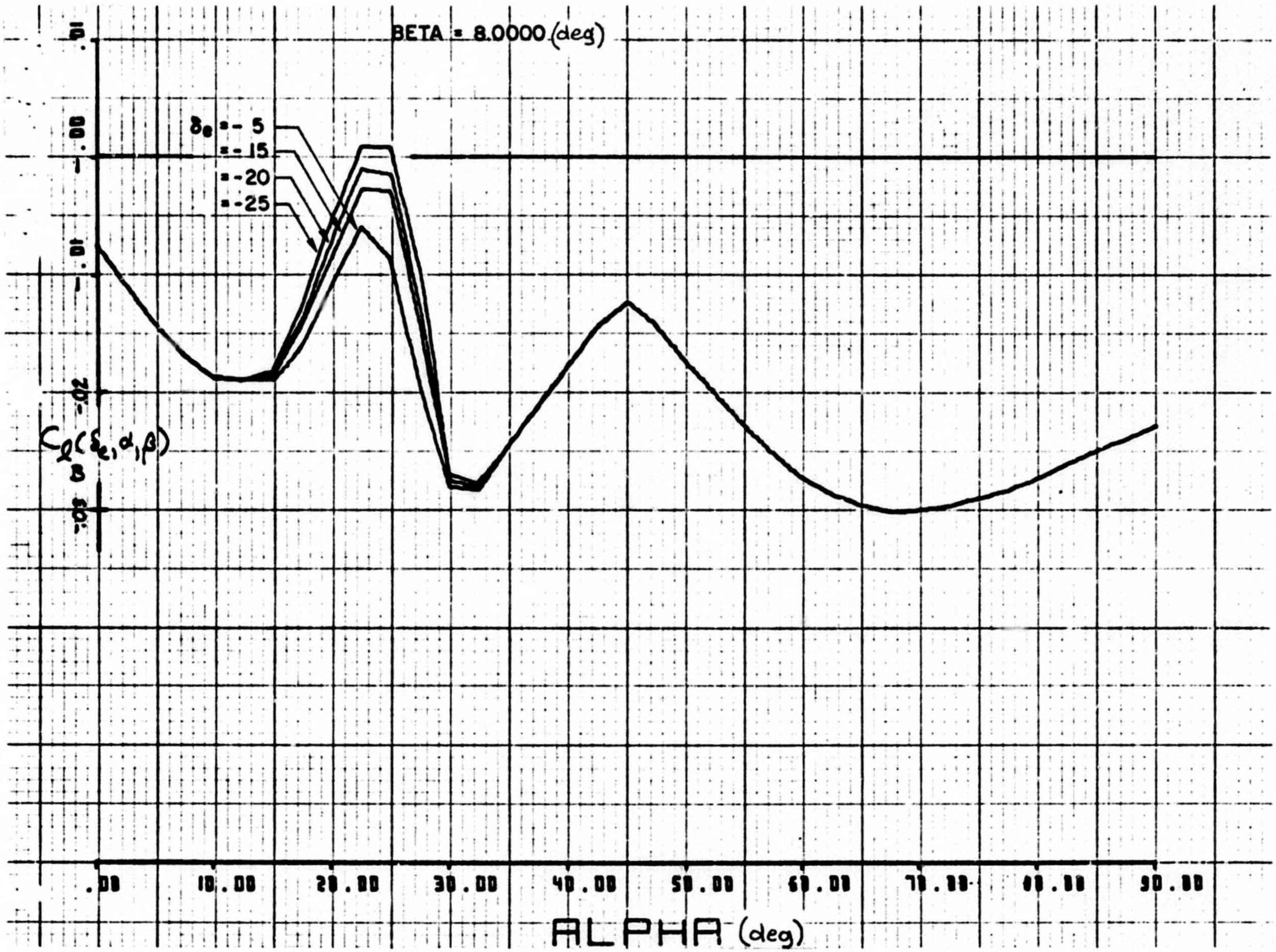


Figure 2. (Continued)

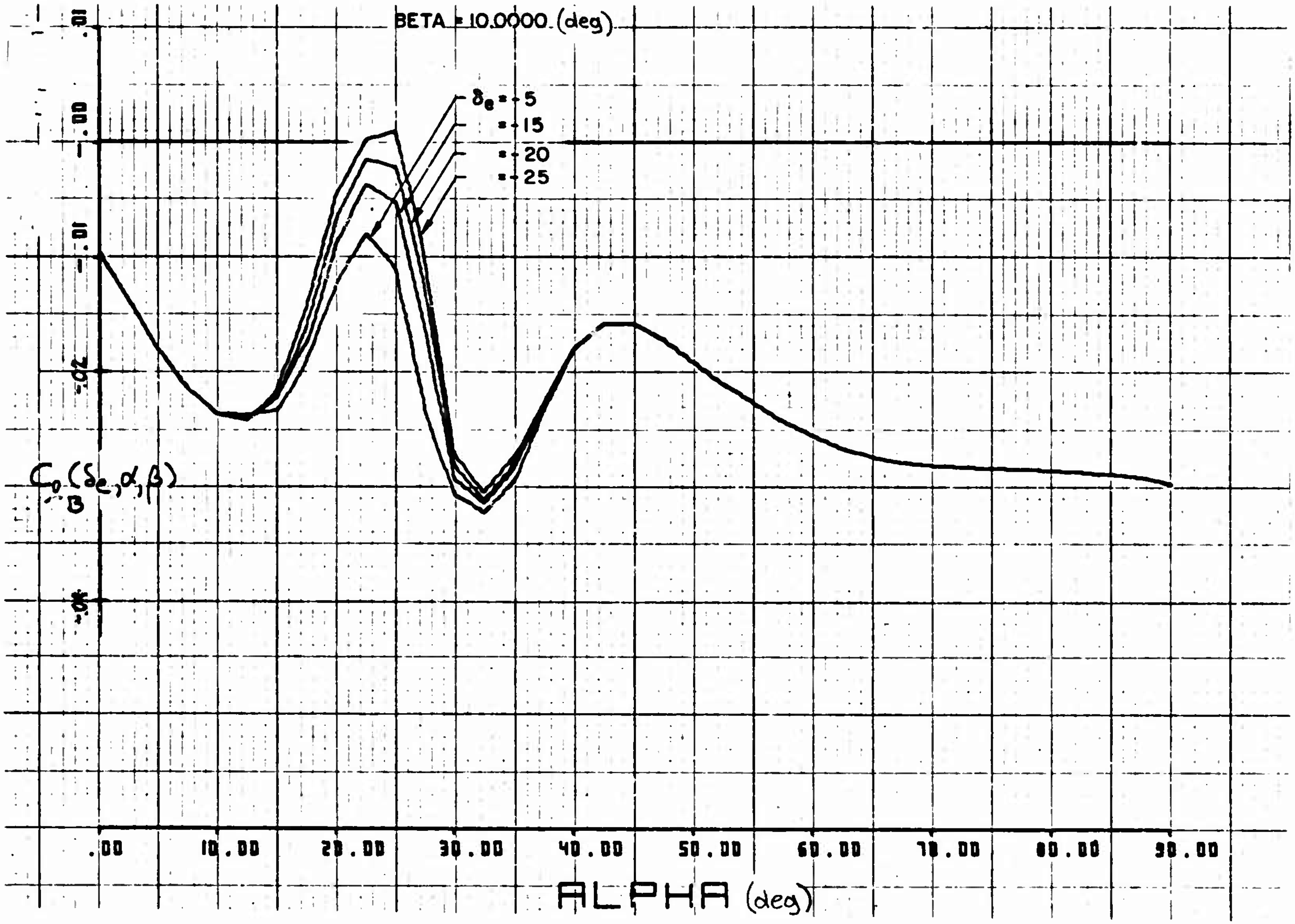


Figure 2. (Continued)

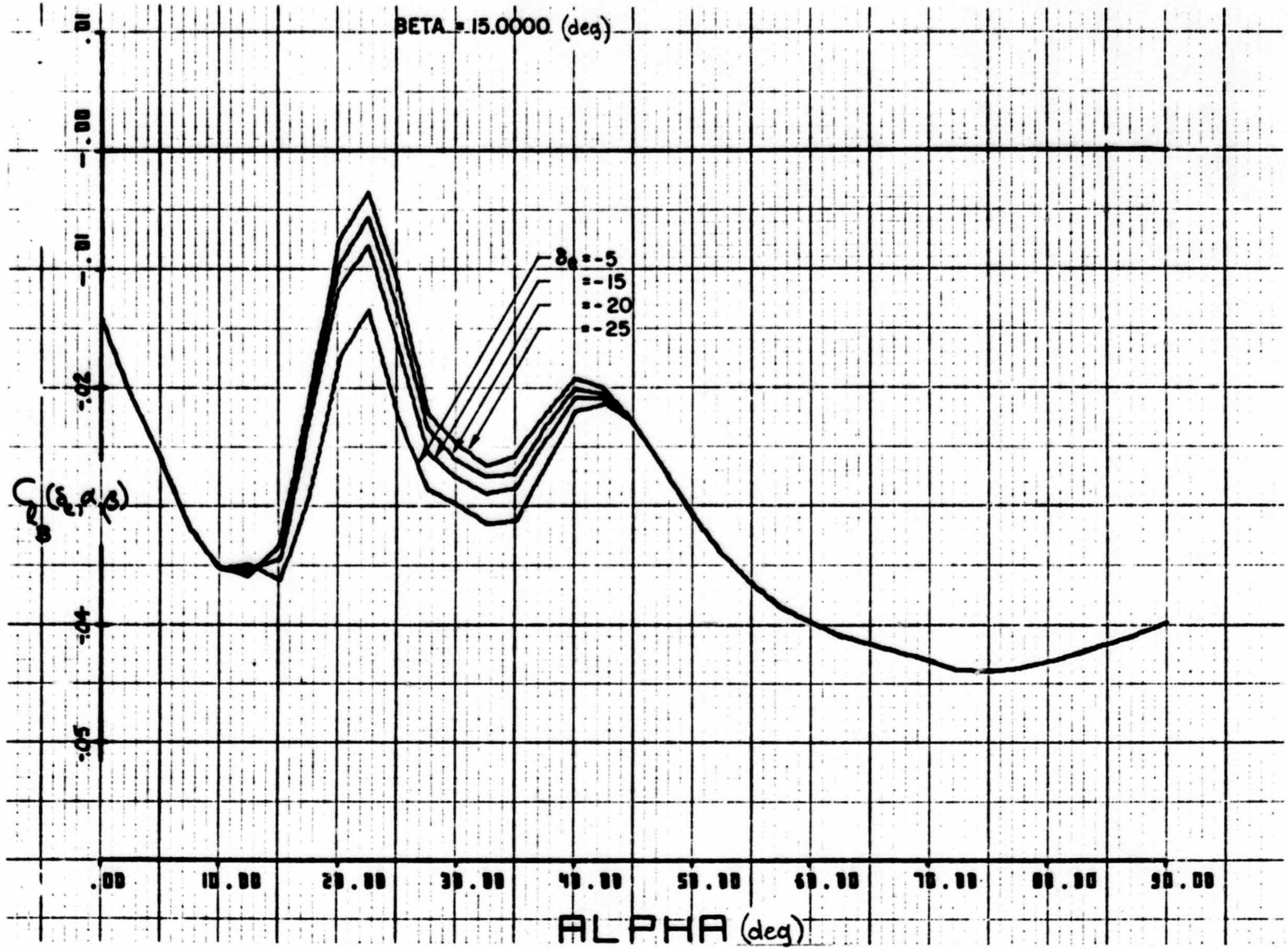


Figure 2. (Continued)

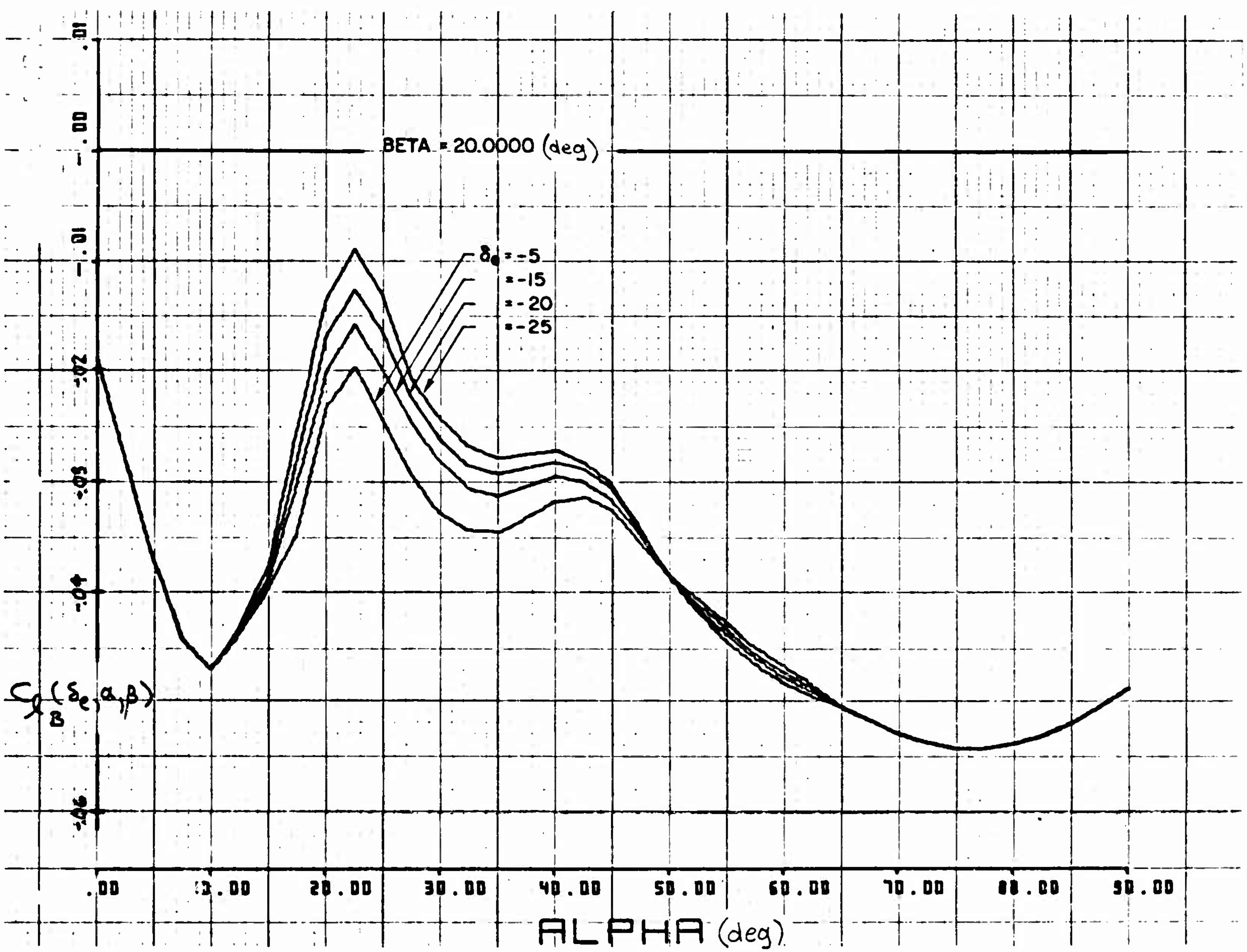


Figure 2. (Concluded)

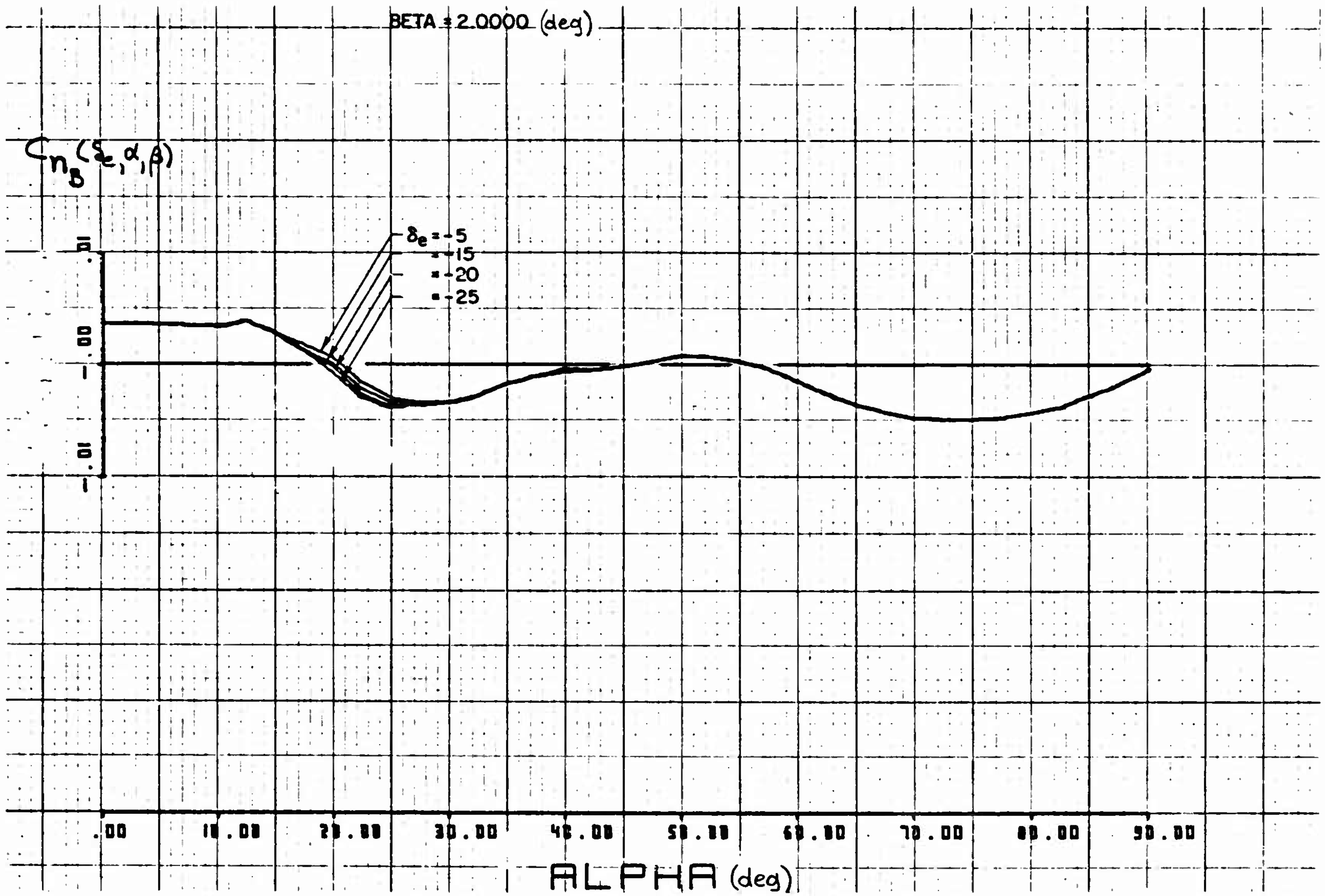
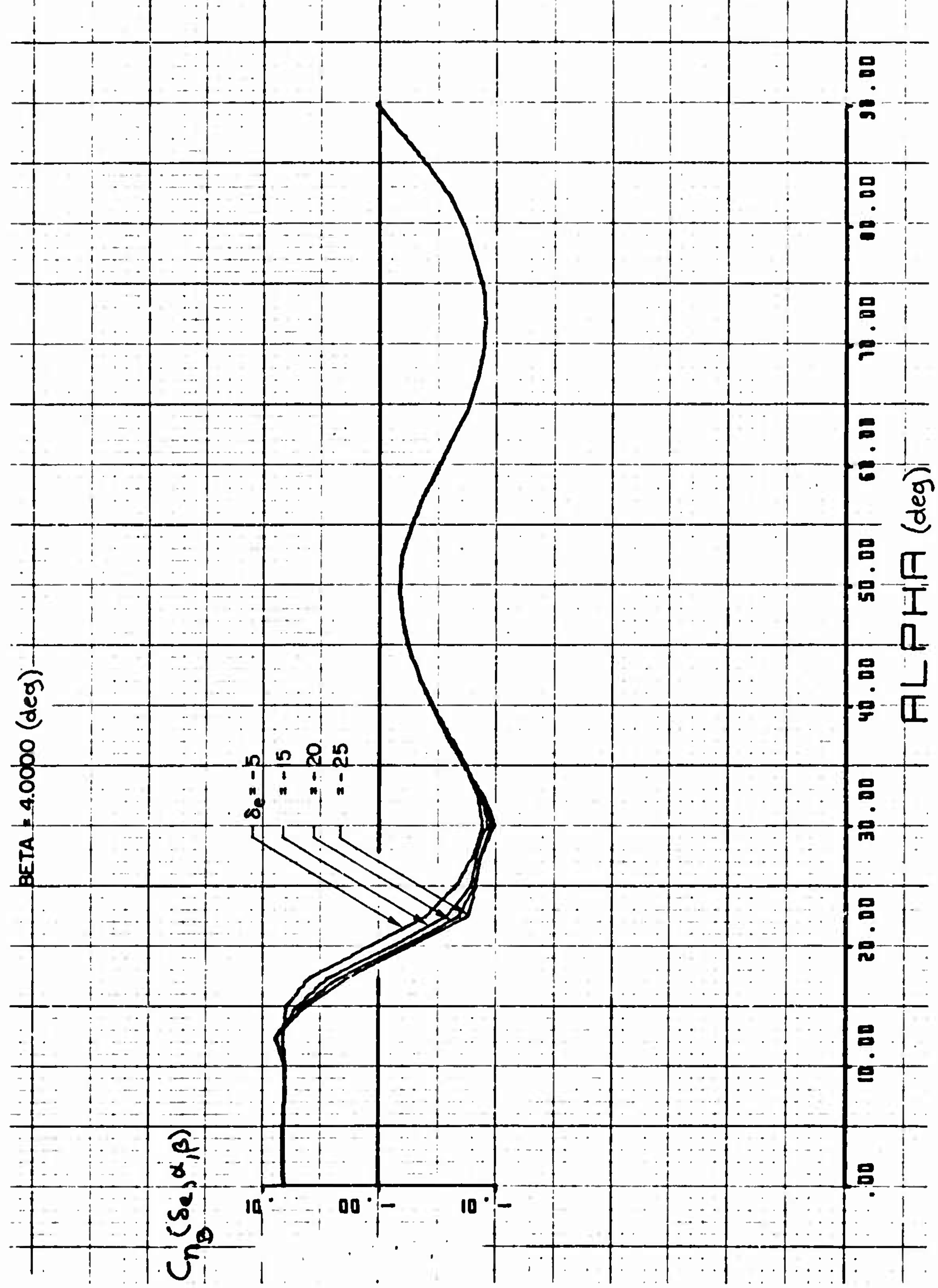


Figure 3. $C_{n_B}(\delta_e,\alpha,\beta)$



BETA = 4.0000 (deg)
δe = -5
= -15
= -20
= -25
Cnβ(δe, α, β)
.00
10.00
20.00
30.00
40.00
50.00
70.00
80.00
90.00
ALPHA (deg)

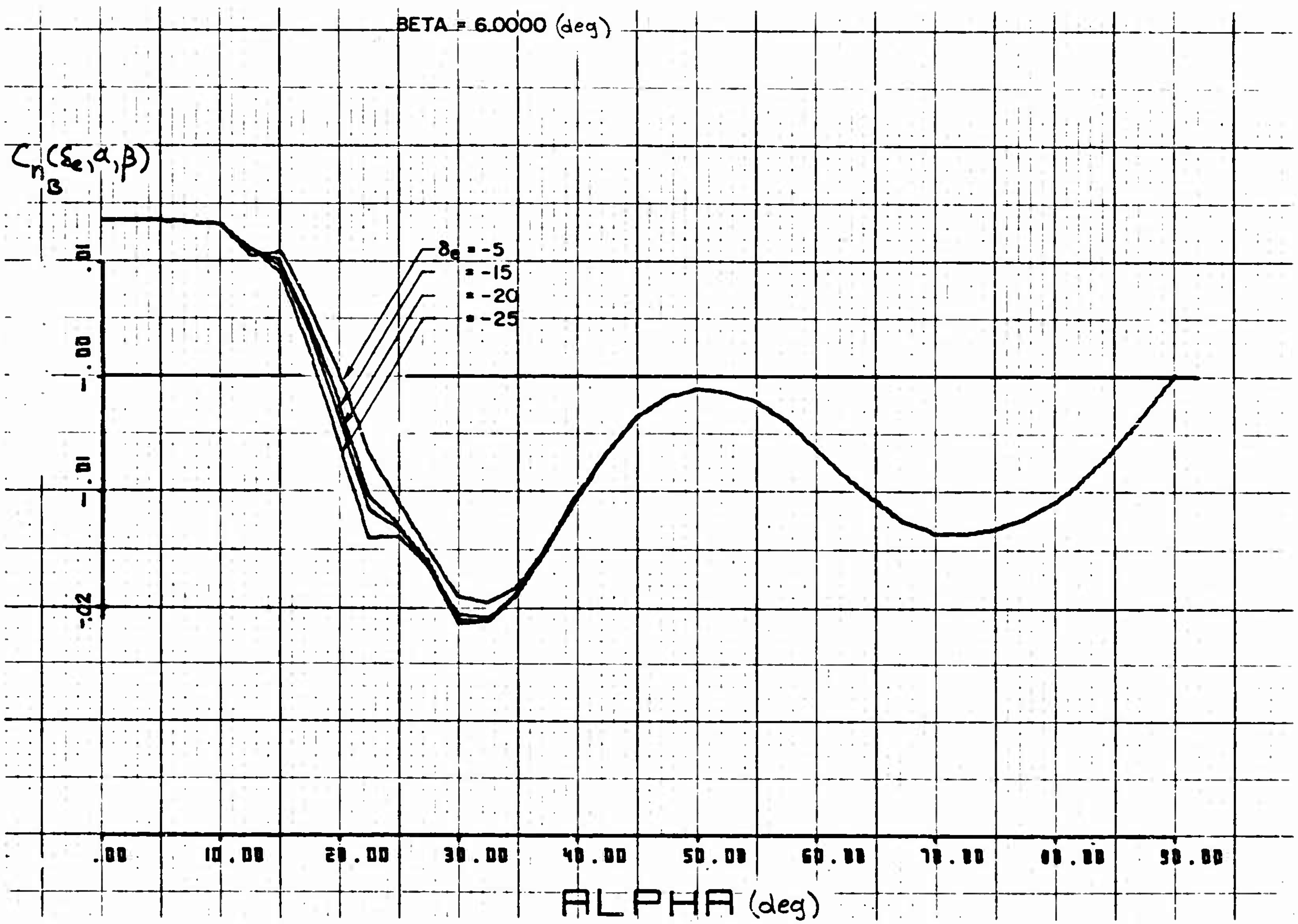


Figure 3. (Continued)

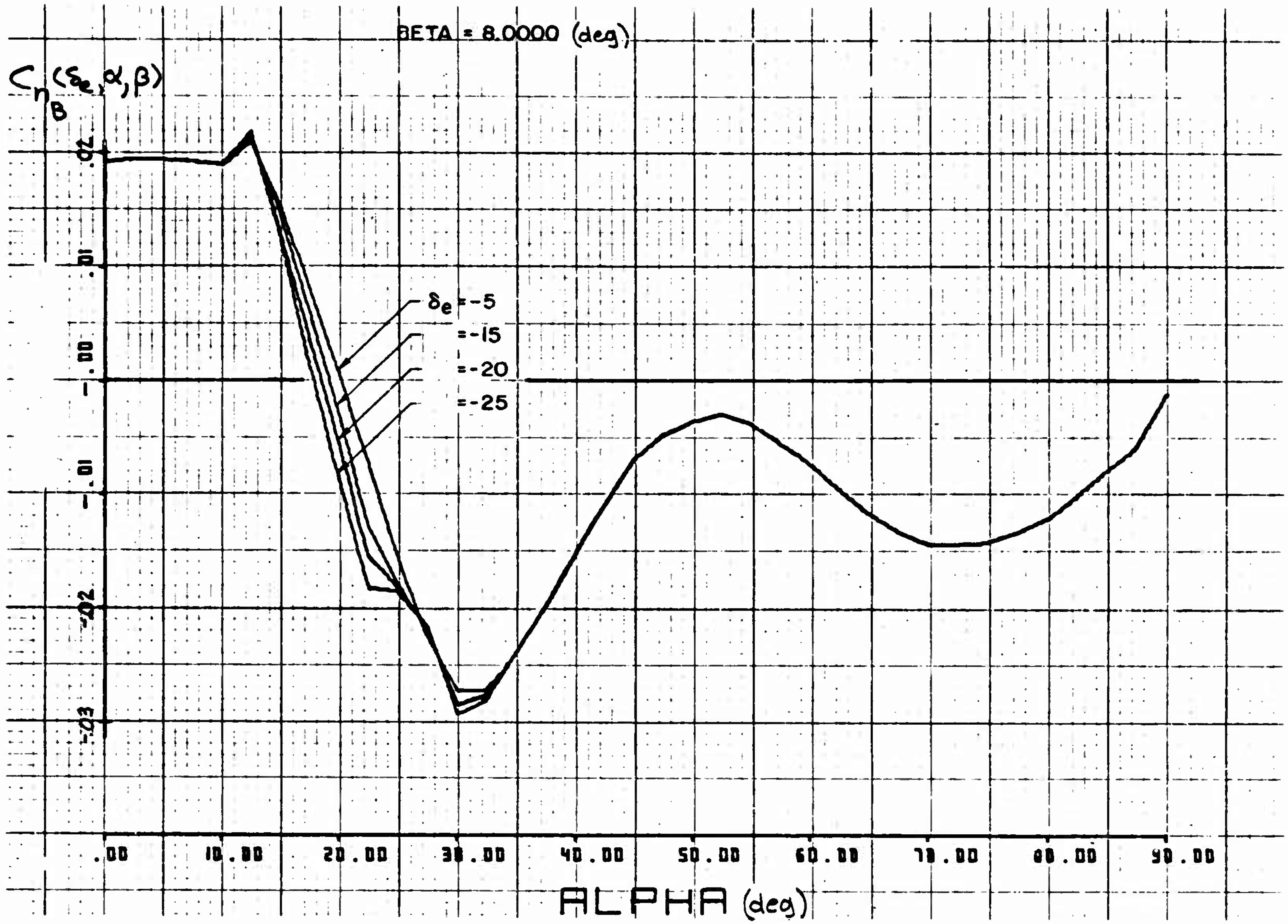


Figure 3. (Continued)

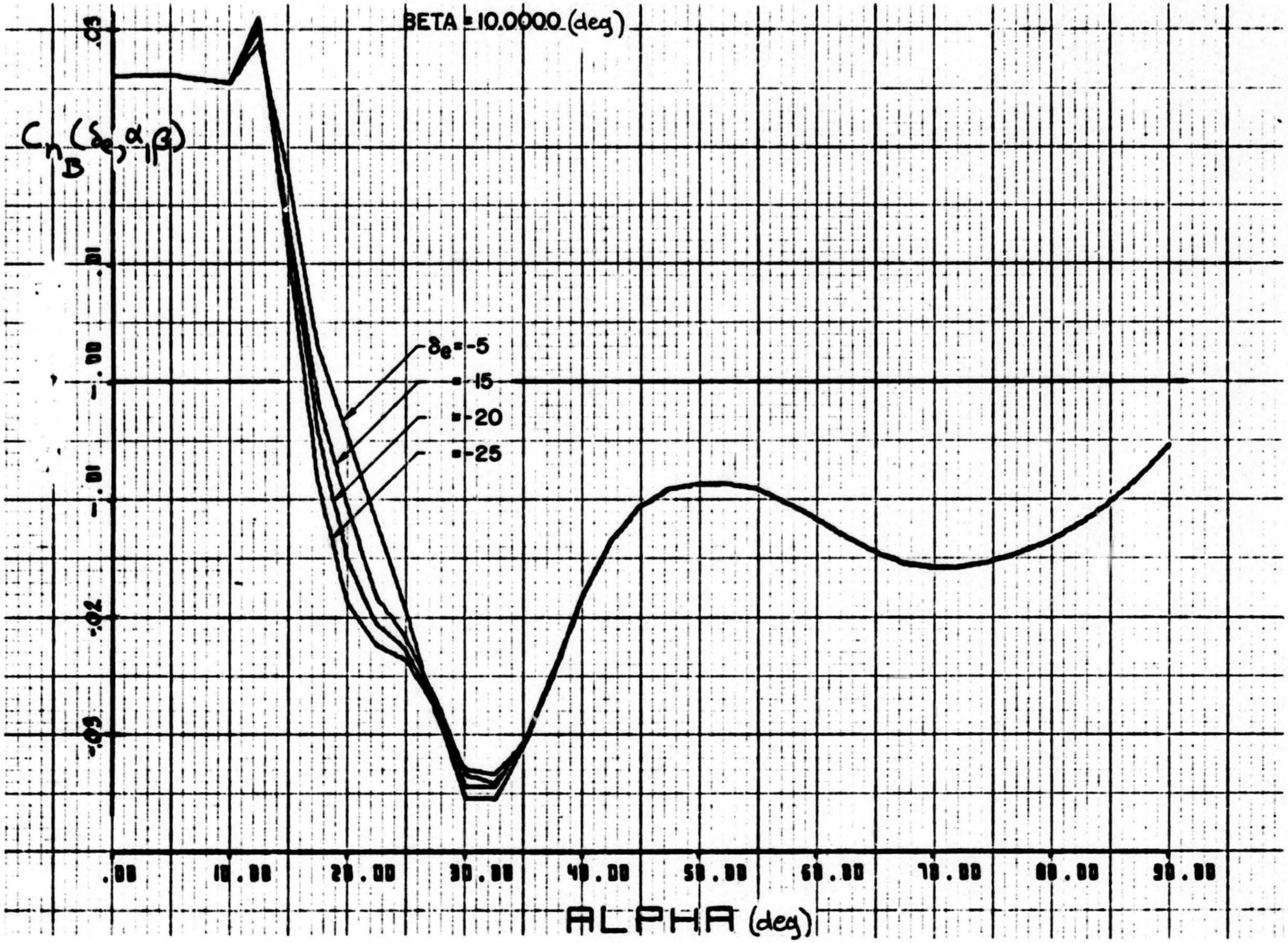


Figure 3. (Continued)

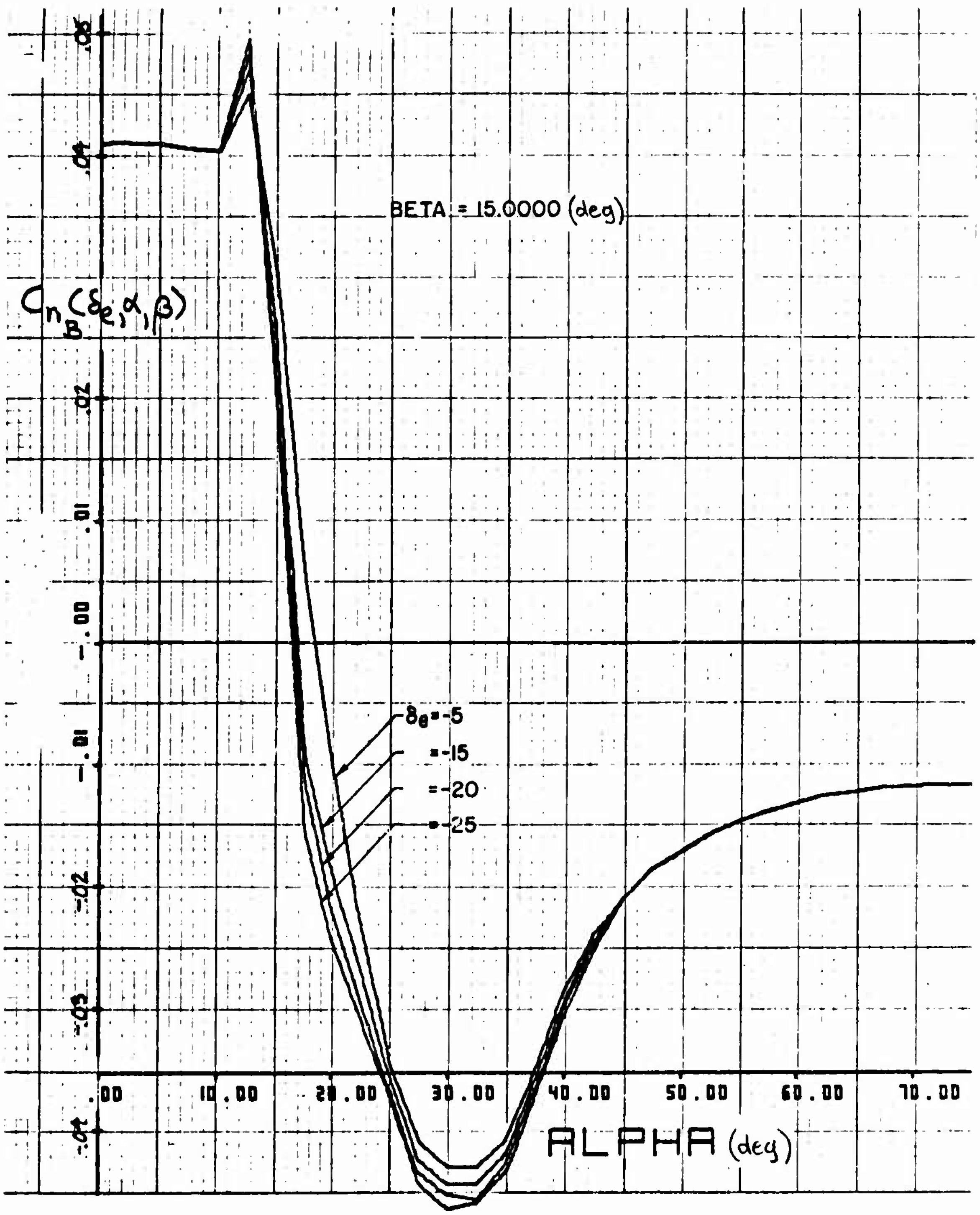


Figure 3. (Continued)

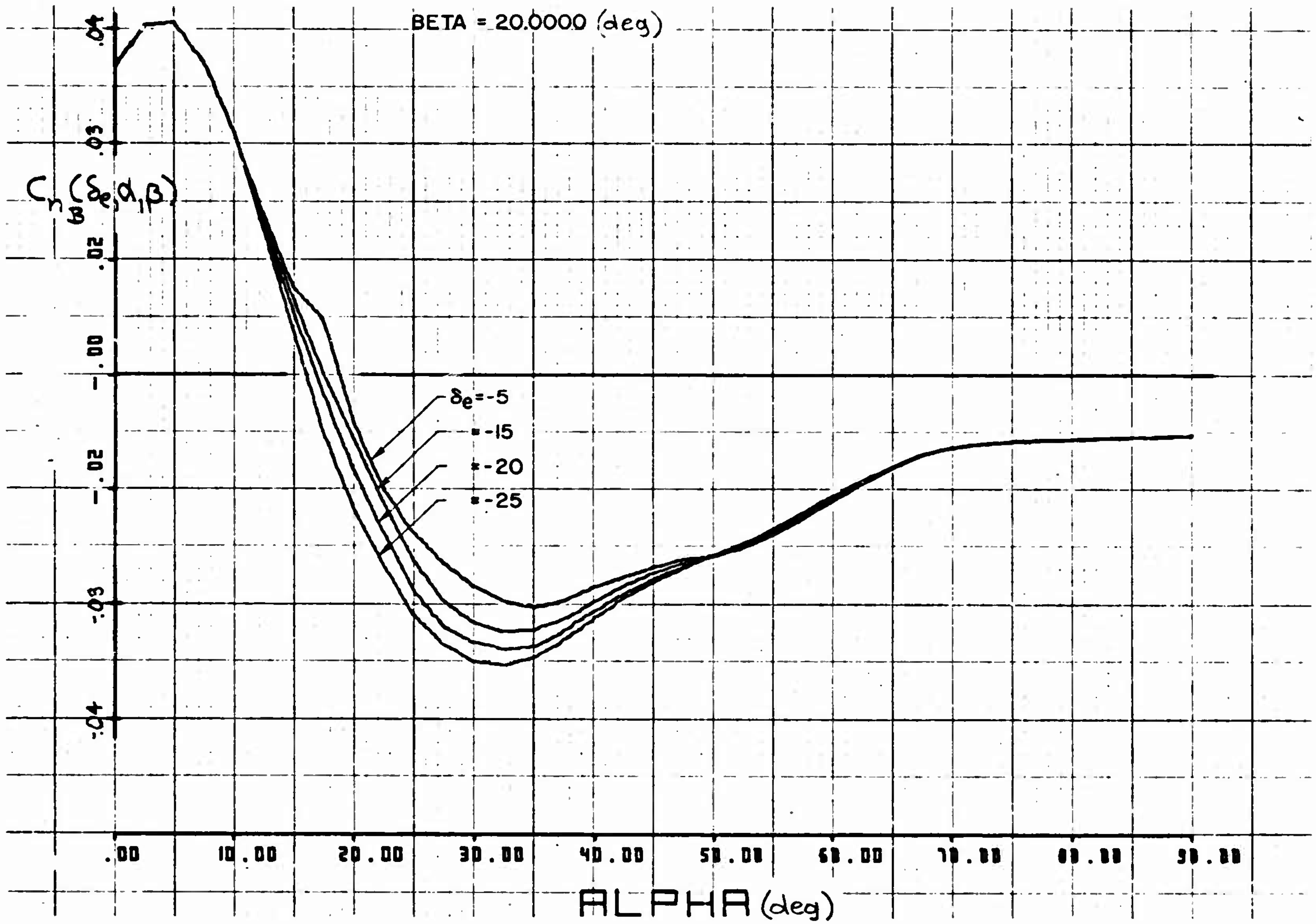


Figure 3. (Concluded)

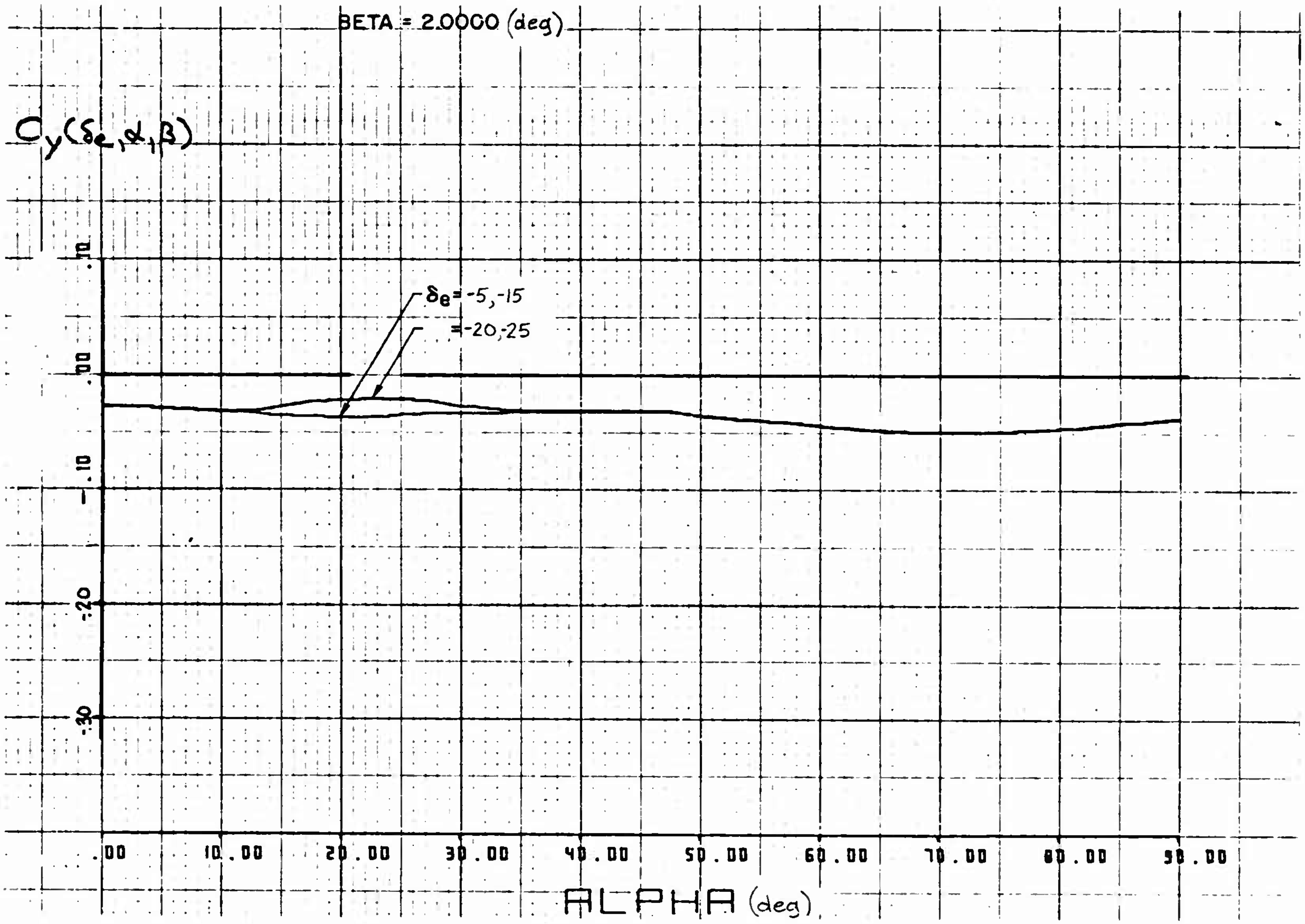


Figure 4. $C_y(\delta_e,\alpha,\beta)$

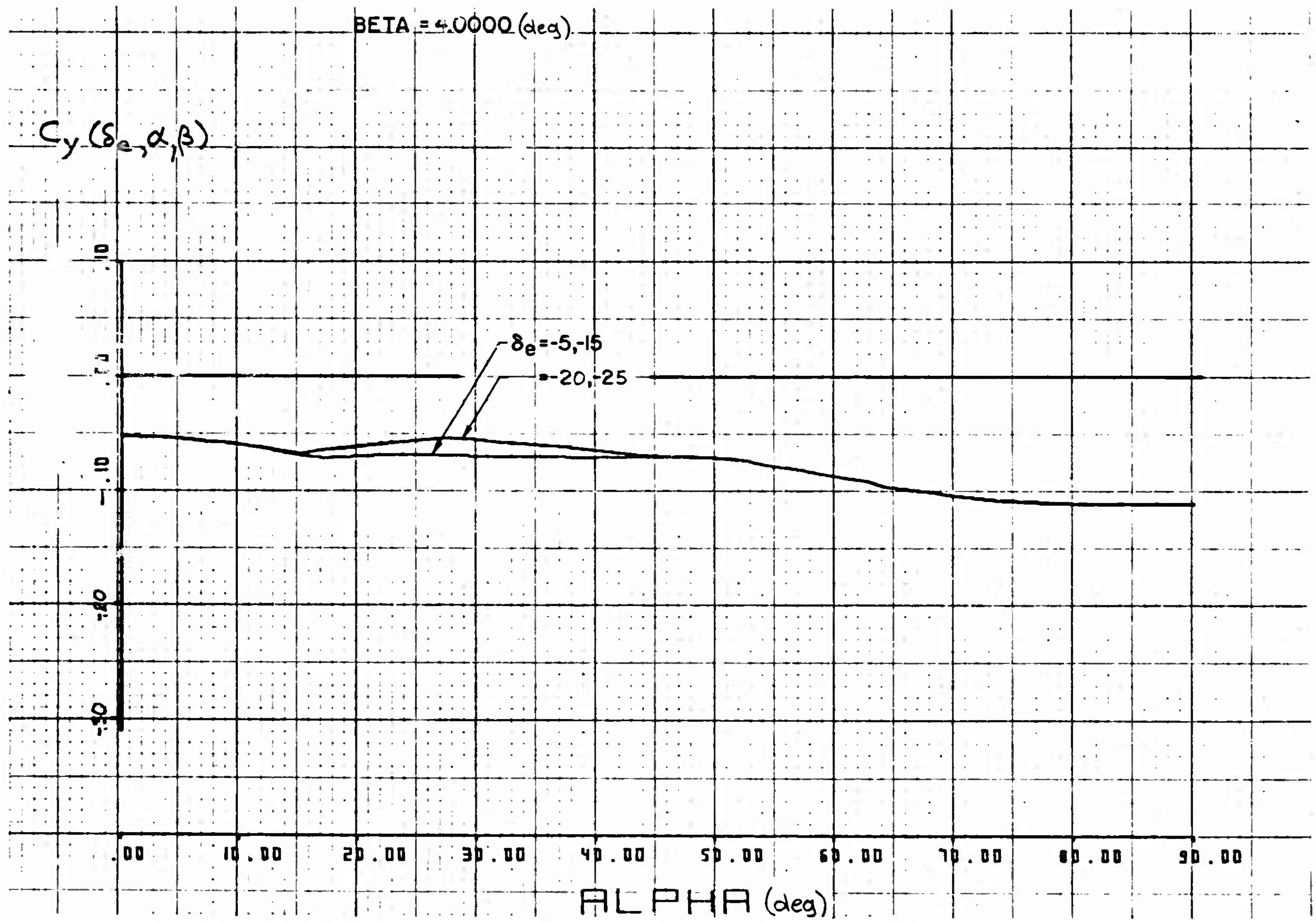


Figure 4. (Continued)

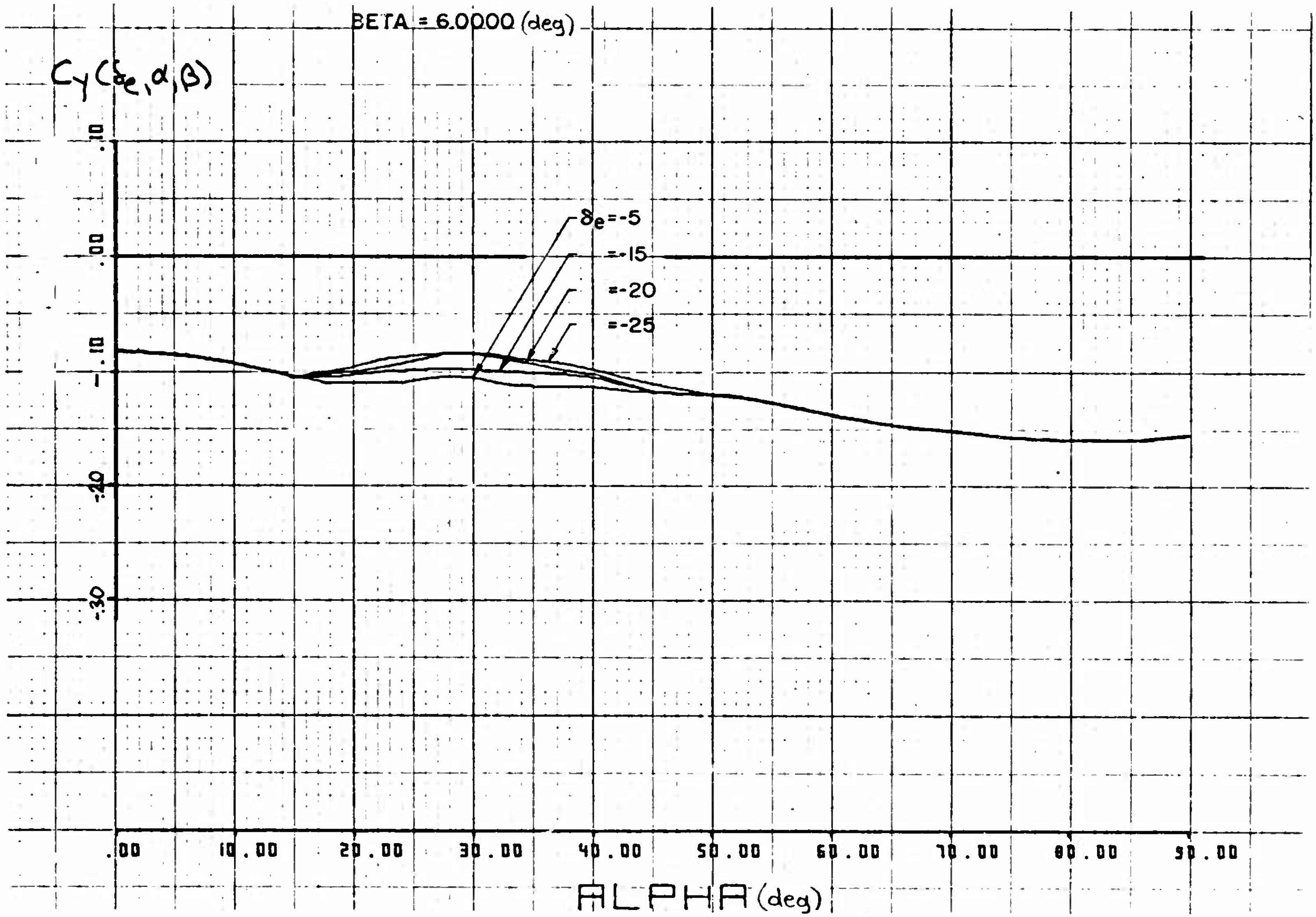


Figure 4. (Continued)

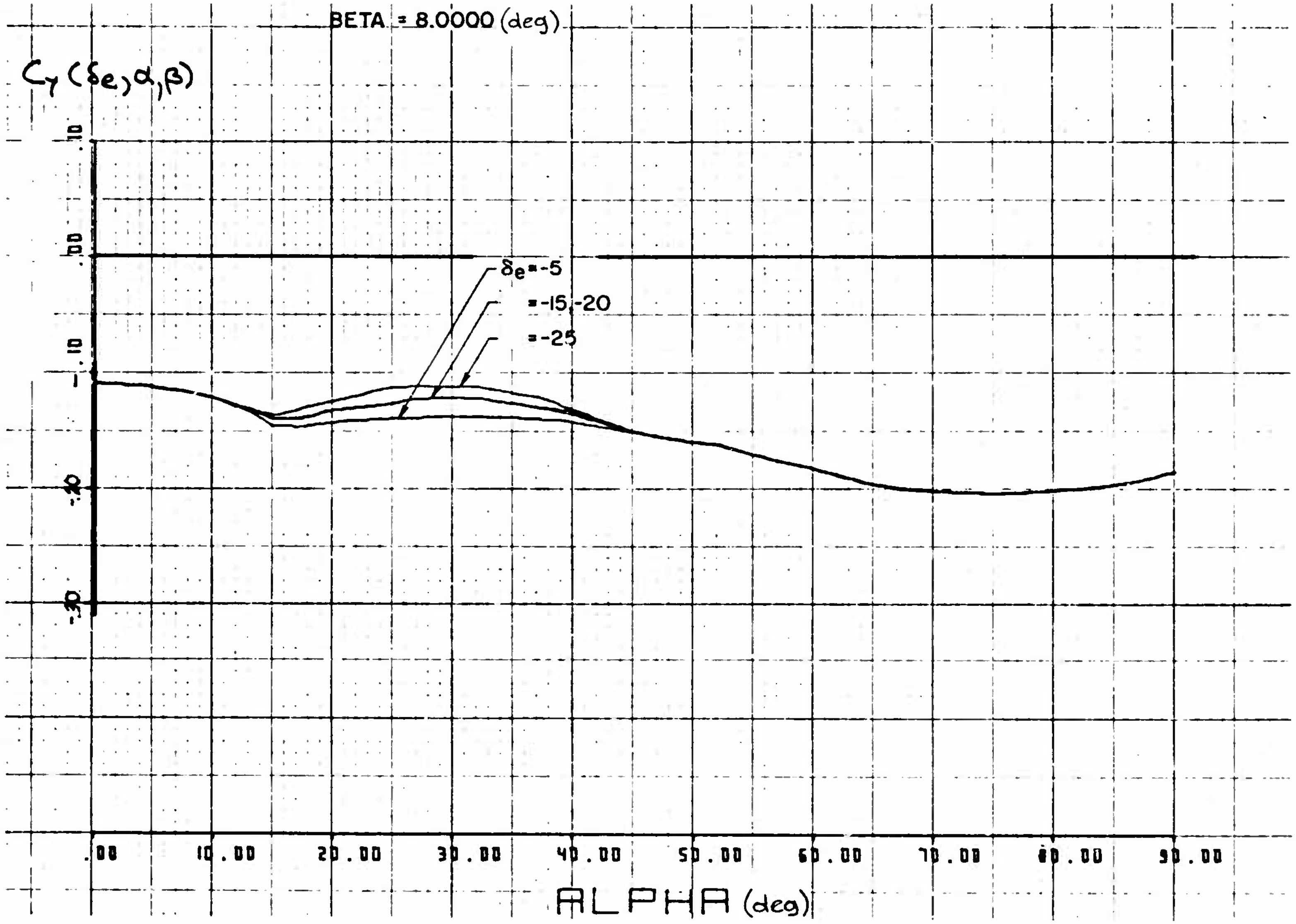


Figure 4. (Continued)

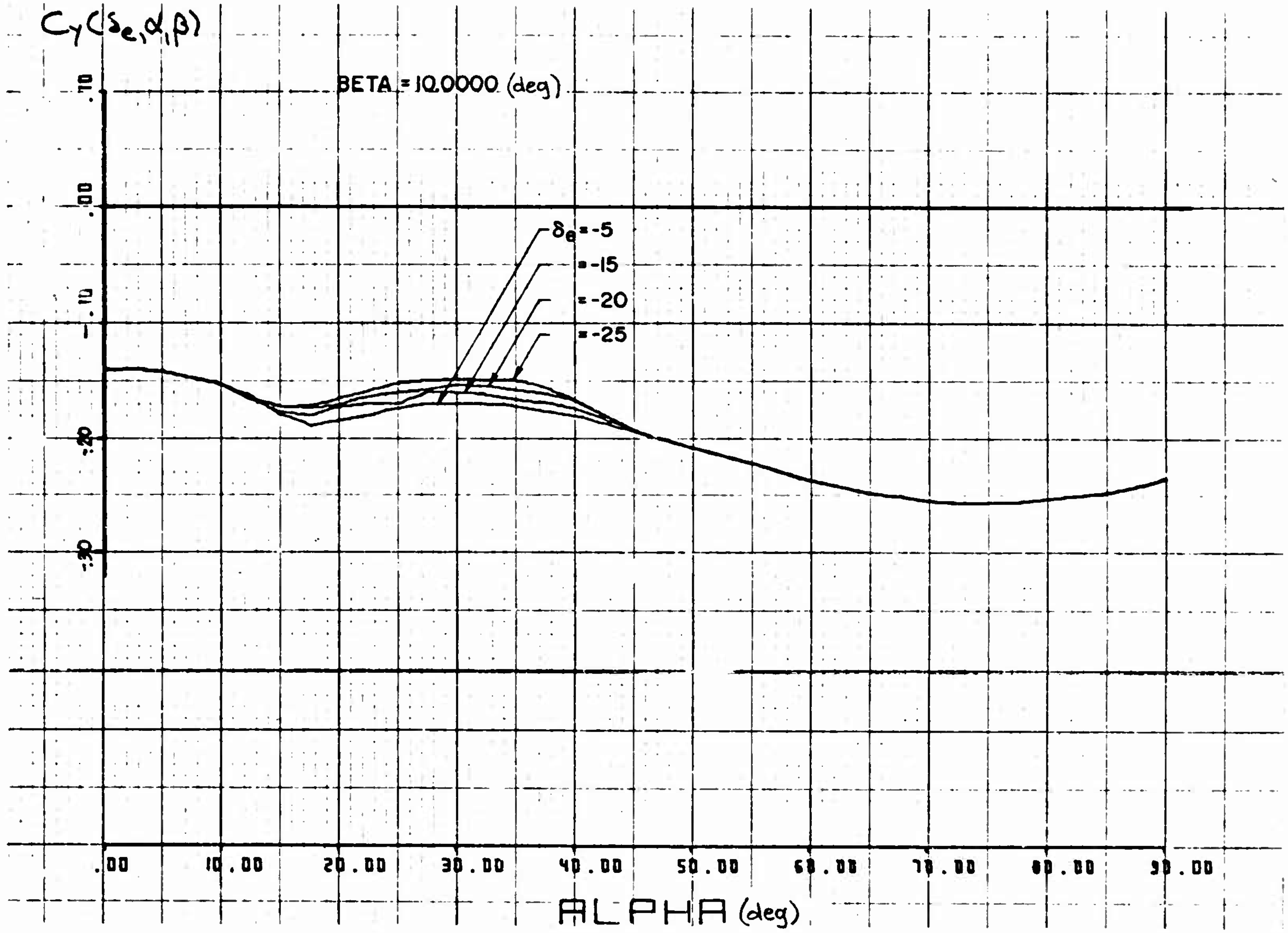


Figure 4. (Continued)

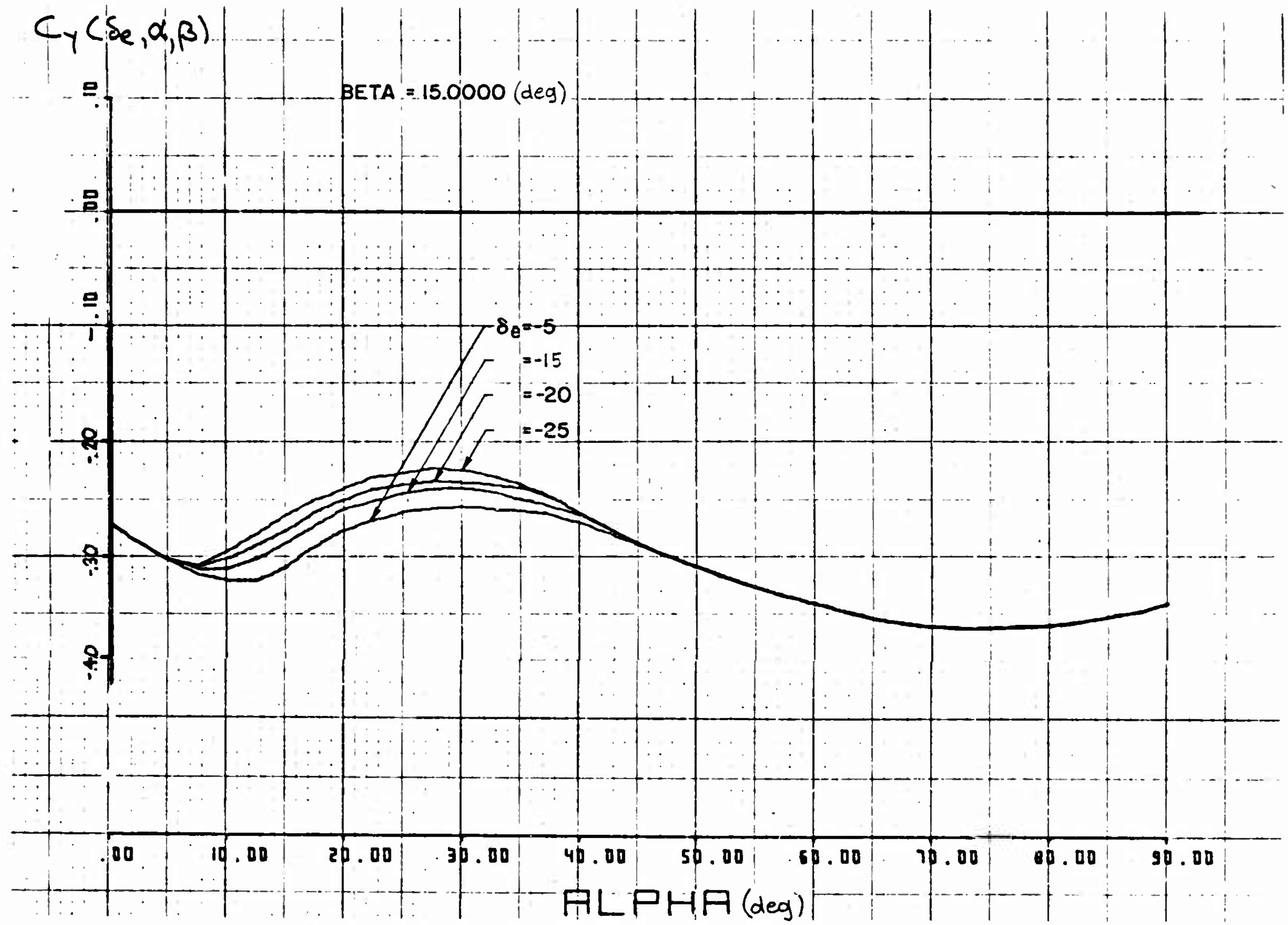


Figure 4. (Continued)

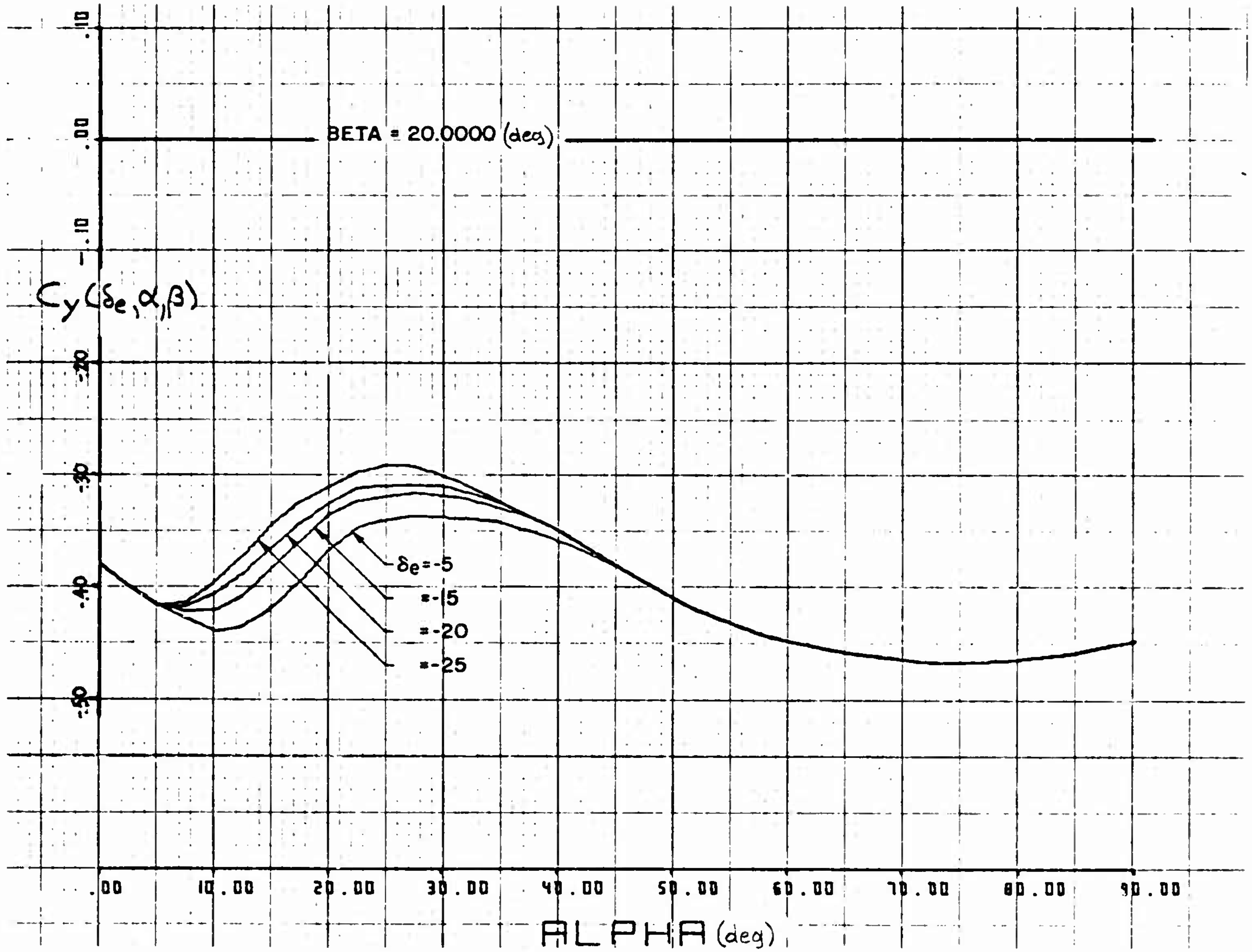


Figure 4. (Concluded)

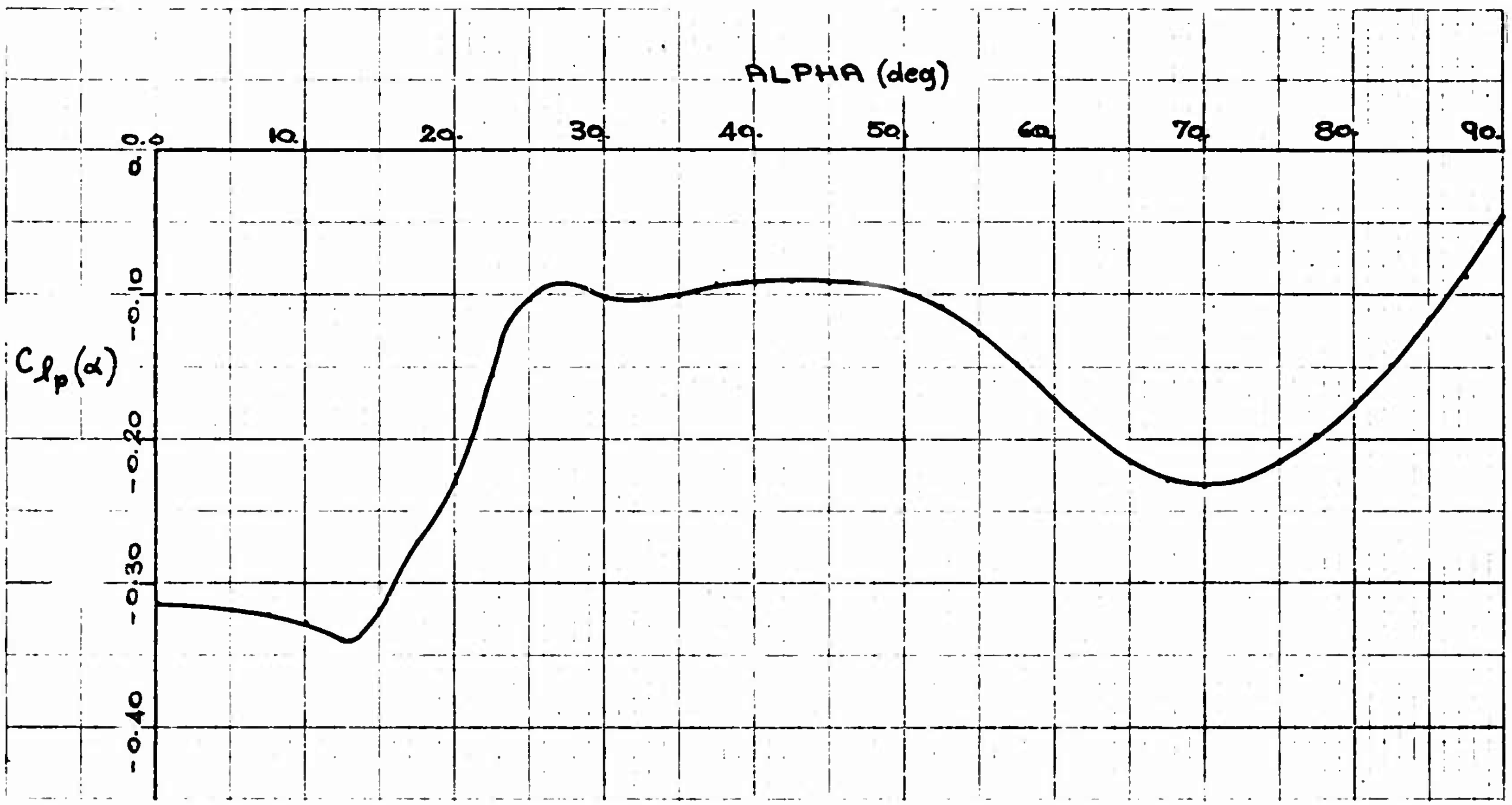


Figure 5. $C_{\ell_p}(\alpha)$

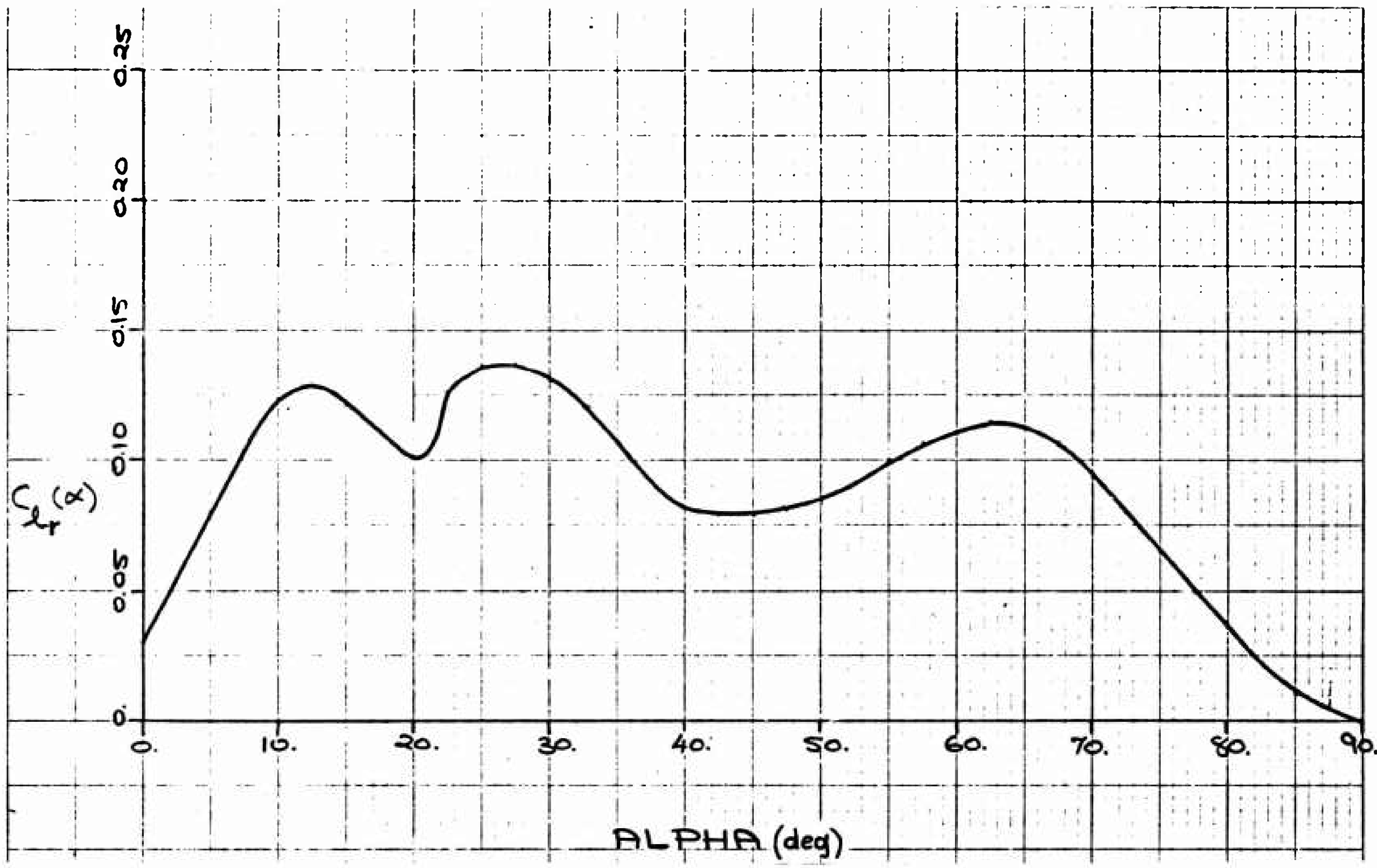


Figure 6. $C_{\ell_r}(\alpha)$

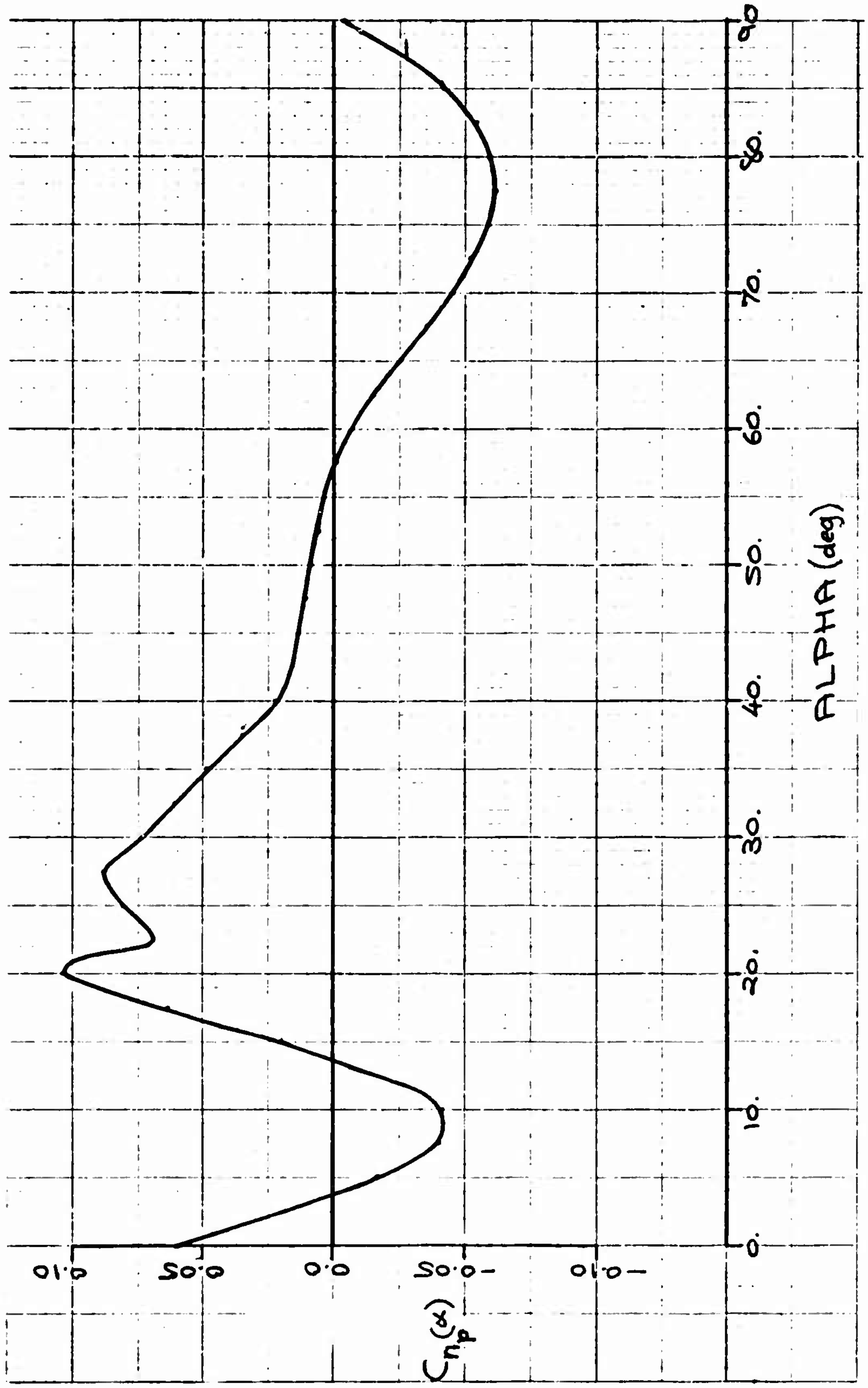


Figure 7. $C_{n_p}(\alpha)$

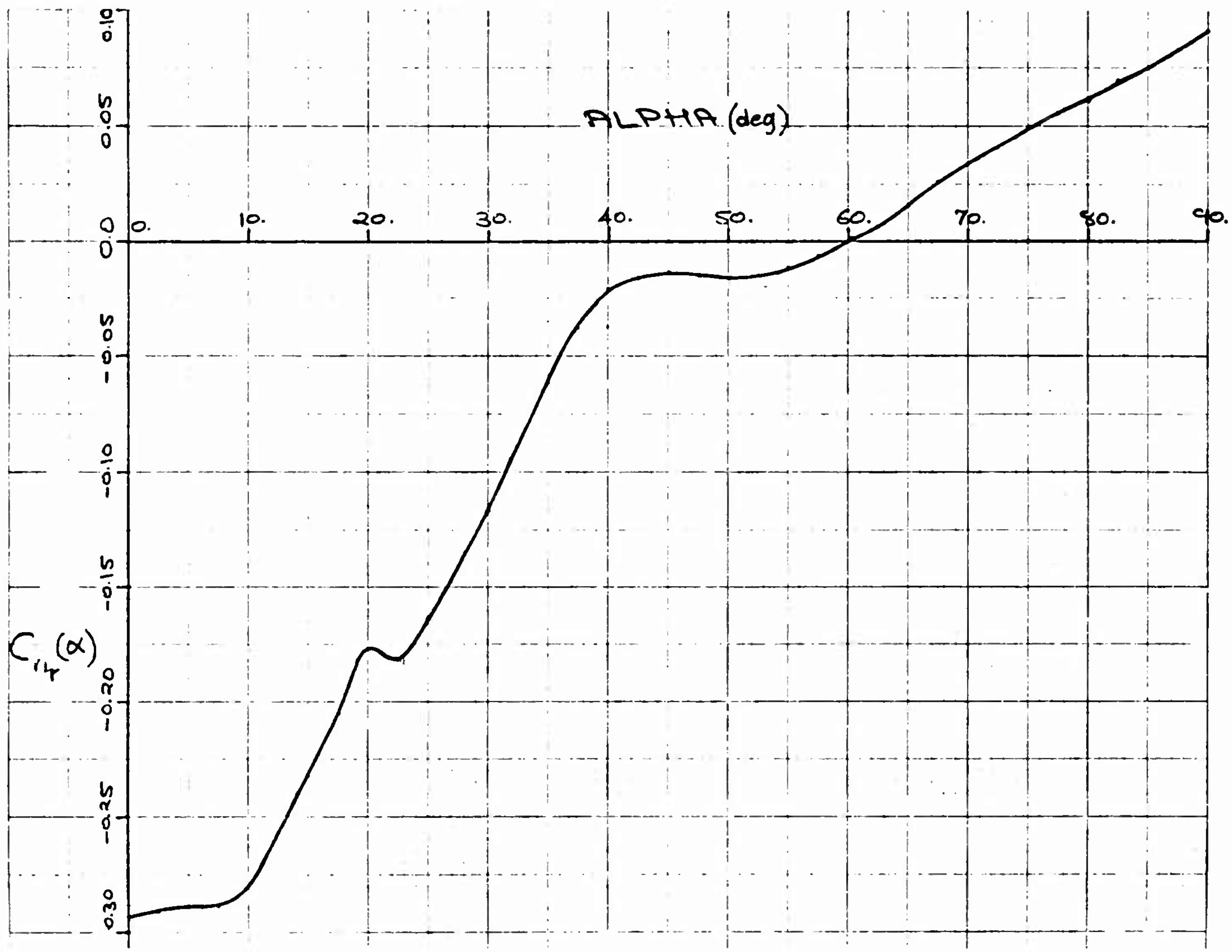


Figure 8. $C_{n_r}(\alpha)$

APPENDIX III

STABILITY DERIVATIVES AND TRANSFER FUNCTIONS

A. TRIM CONDITIONS

Dimensional stability derivatives are based on the following trim and inertia values:

$h = 13,200$ ft	$I_{x_B} = 16,970$ slug-ft^2
$W = 22,699$ lb	$I_{y_B} = 65,430$ slug-ft^2
$\gamma_o = \Phi_o = 0$	$I_{z_B} = 76,130$ slug-ft^2
$P_o = Q_o = R_o = 0$	$I_{xz_B} = 4030$ slug-ft^2
$S = 375$ ft^2	$X_{cg} = 29.6$ % MAC
$\bar{c} = 10.84$ ft	Gear up
$b = 38.7$ ft	Flaps up

Aircraft trim was accomplished using the digital program reported by Johnson* and the nonlinear aerodynamic lookup tables of Appendix II. Aircraft velocity and sideslip angle were preselected and the digital program then determined α_o, T_o, δ_{e_o}, δ_{a_o}, and δ_{r_o}.

B. DIMENSIONAL DERIVATIVES

Dimensional derivatives were obtained by perturbing each state variable of the equations summarized in Fig. 9 and obtaining the appropriate partial derivatives with respect to that state variable. Aerodynamic forces and moments are obtained from the nonlinear coefficient lookup tables of Appendix II. Derivatives were generated for zero β and a range of α's above and below stall (approximately 21 deg). Lateral derivatives were

*Johnson, Walter A., and Gary L. Teper, Analysis of Vortex Wake Encounter Upsets, Systems Technology, Inc., TR-1025-2, Apr. 1974 (forthcoming NASA CR-)

$$\dot{\alpha} = Q - P\cos\alpha\tan\beta - R\sin\alpha\tan\beta + \frac{1}{mV_T\cos\beta}\Big\{W(\sin\Theta\sin\alpha + \cos\Theta\cos\Phi\cos\alpha) - T\sin(\alpha + \xi_o) - L\Big\}$$

$$\dot{\beta} = P\sin\alpha - R\cos\alpha + \frac{1}{mV_T}\Big\{W(\cos\Theta\sin\Phi\cos\beta + \sin\Theta\cos\alpha\sin\beta - \cos\Theta\cos\Phi\sin\alpha\sin\beta) - T\sin\beta\cos(\alpha + \xi_o) + Y_A\cos\beta + D\sin\beta\Big\}$$

$$\dot{V}_T = \frac{1}{m}\Big\{T\cos\beta\cos(\alpha + \xi_o) + W[\cos\Theta\cos\Phi\sin\alpha\cos\beta - \sin\Theta\cos\alpha\cos\beta + \cos\Theta\sin\Phi\sin\beta] + Y_A\sin\beta - D\cos\beta\Big\}$$

$$\dot{P} = (C_1R + C_2P)Q + C_3\mathcal{L} + C_4N$$

$$\dot{Q} = C_5RP + C_6(R^2 - P^2) + C_7M$$

$$\dot{R} = (C_8P + C_9R)Q + C_4\mathcal{L} + C_{10}N$$

$$\dot{\Psi} = (R\cos\Phi + Q\sin\Phi)/\cos\Theta$$

$$\dot{\Theta} = Q\cos\Phi - R\sin\Phi$$

$$\dot{\Phi} = P + \Psi\sin\Theta$$

Note: See Appendix I for definition of terms.

Figure 9. Equation Summary

generated in body (centerline) axes and stability axes derivatives were calculated from these. Longitudinal derivatives are presented in Fig. 10 and lateral derivatives in Fig. 11. Derivative values for two non-zero sideslip cases (i.e., β_o = 6 deg and 15 deg) are also identified and indicate that only Y_β, $\mathcal{L}'_\beta$, and N'_β have significant variation with β. The latter along with their counterparts Y_α, $\mathcal{L}'_\alpha$, and N'_α are plotted as functions of α and β in Fig. 12.

C. UNCOUPLED LATERAL-LONGITUDINAL TRANSFER FUNCTIONS

Longitudinal transfer function factors for ten symmetric flight conditions are tabulated in Table 1. Lateral factors are presented in Table 2 for stability axis and Table 3 for body (centerline) axis. Plots of the pole-zero migration with increasing angle of attack are presented in Figs. 13 and 14.

D. COUPLED NONSYMMETRIC LATERAL-LONGITUDINAL TRANSFER FUNCTIONS

Coupled six-degrees-of-freedom transfer function factors for α_o = 18.8 deg, β_o = 6 deg are presented in Table 4. Those for α_o = 19.3 deg, β_o = 15 deg are presented in Table 5. A full complement of coupling numerators were calculated for the 19.3/15 deg case; however, only one, $N^{p\ q}_{\delta_e \delta_a}$, was obtained for the $18.8^o\alpha_o/6^o\beta_o$ case. The following relationships hold for coupling numerators:

$$N^{x,y}_{i,j} = -N^{x,y}_{j,i}$$

$$N^{\dot{x},\dot{y}}_{i,j} = sN^{x,y}_{i,j}$$

The format for the digital printout is as follows:

Unless otherwise specified, the denominator is the first data ouput. The computer will identify it by typing:

DENOMINATOR:

The denominator is in factored form, giving first the highest order nonzero coefficient of the polynomial, the real roots, complex roots, and finally the lowest order nonzero coefficient. The highest order coefficient is not delimited by parentheses. Real roots (positive for root in left half of s plane) are printed within single parentheses. Complex roots are printed one pair on a line in either the format

$$((\zeta, \omega, \zeta\omega, \omega\sqrt{1 - \zeta^2}))$$

or

$$[\zeta, \omega, \zeta\omega, \omega\sqrt{1 - \zeta^2}]$$

The lowest order coefficient is contained within angle brackets, < >. The numerator of that transfer function is then printed with the same format as the denominator and are identified as follows:

NUMERATOR AAA/BBB

Coupling numerators and coupling-coupling numerators will be identified in the following manner:

NUMERATOR: AAA/BBB, CCC/DDD

NUMERATOR: AAA/BBB, CCC/DDD, EEE/FFF

Again, output is in the same format as above.

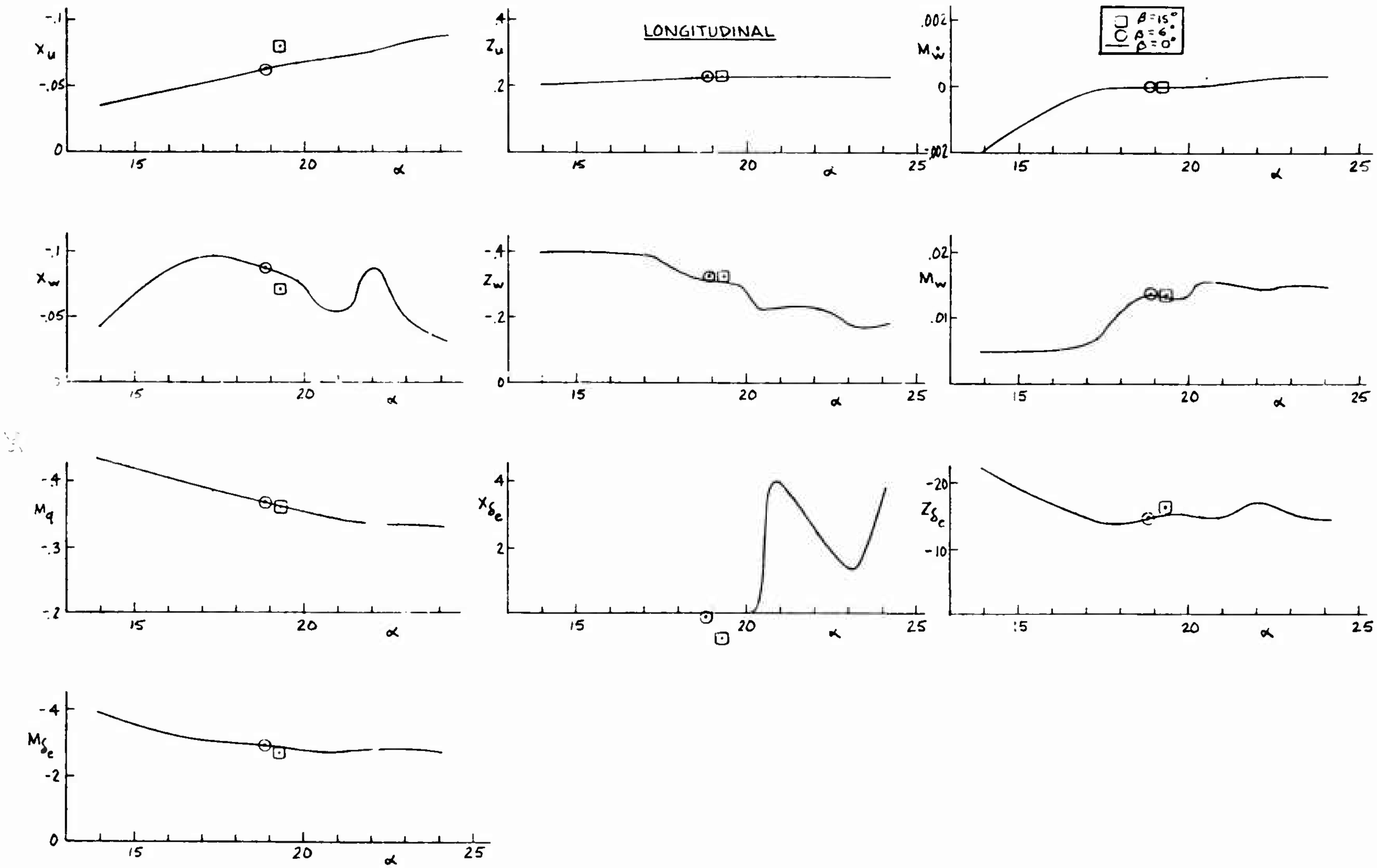


Figure 10. Longitudinal Derivatives

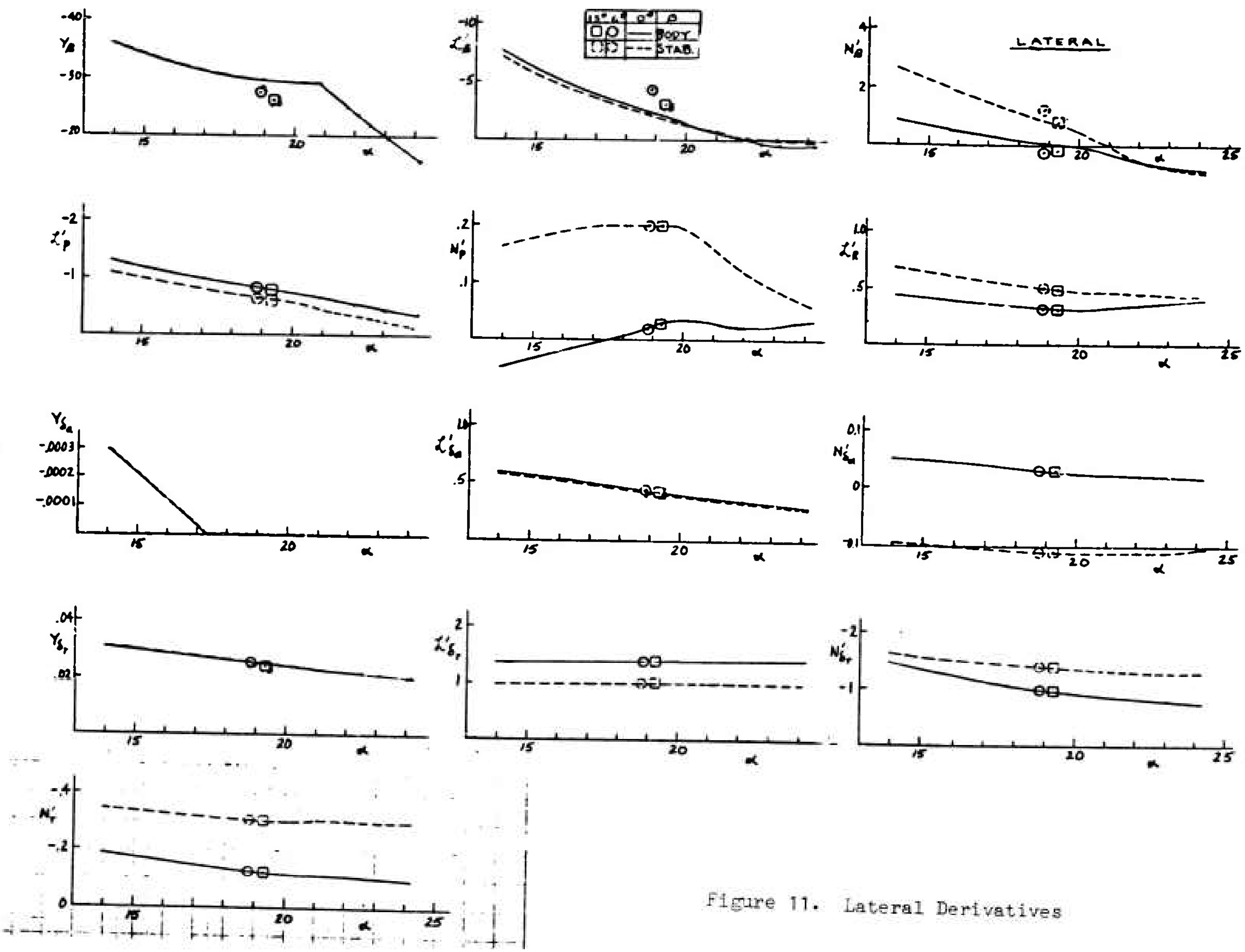


Figure 11. Lateral Derivatives

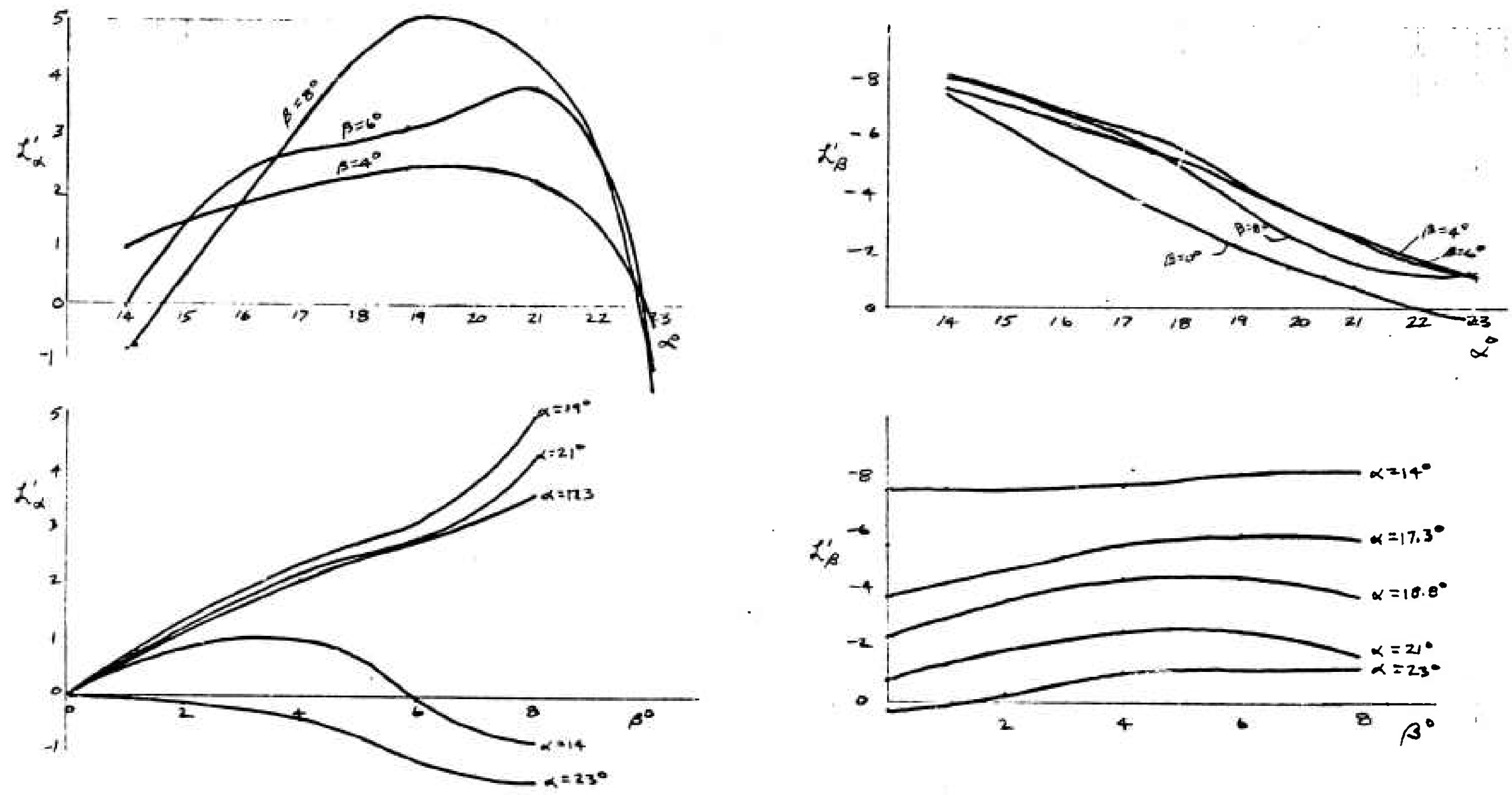


Figure 12. Variation of Lateral Derivatives with α and β

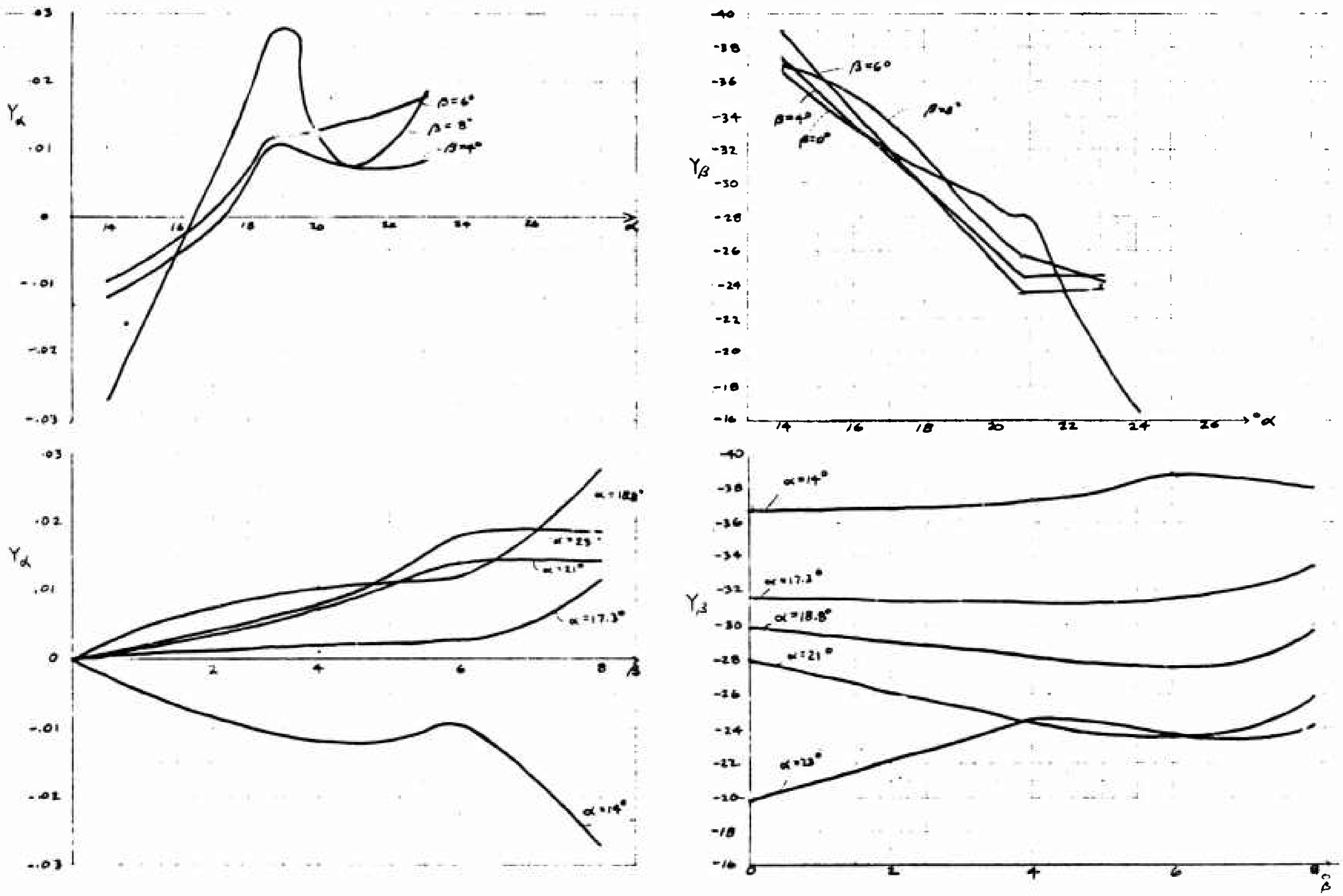


Figure 12. (Continued)

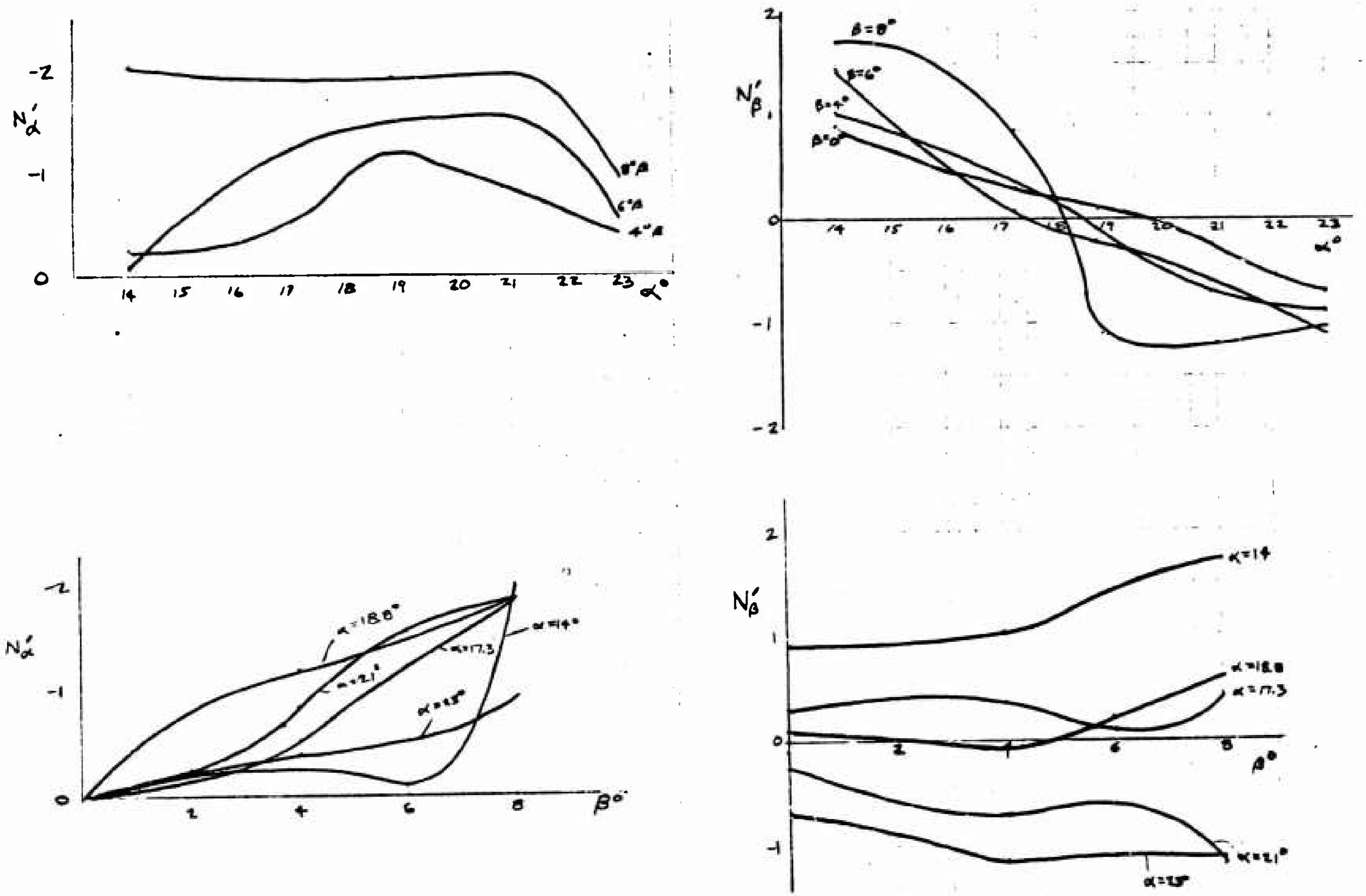


Figure 12. (Concluded)

TABLE 1

LONGITUDINAL TRANSFER FUNCTION FACTORS
A-7 Data; 13,200 ft Altitude

α°		10.0	14.6	17.3	18.8	19.8	20.4	20.9	22.1	23.1	24.2
β°		0	0	0	0	0	0	0	0	0	0
V_0	FPS	360	300	270	260	254	252	250	246	243	240
δ_{c_0}	DEG	-6.88	-8.62	-10.47	-12.27	-13.50	-14.23	-14.95	-16.52	-17.82	-19.27
T_0	LB.	2150	3855	5281	5954	6486	6617	6896	7306	7750	8200
Δ	ζ_{PH}	.051	.082	.127	.167	.181	.193	.199	.209	.227	.239
	ω_{PH}	.121	.141	.158	.166	.169	.170	.171	.172	.174	.174
	ζ_{SP}	.312	.359	.294	.186	.174	.140	.137	.133	.113	.113
	ω_{SP}	2.02	1.28	1.411	1.912	1.875	2.000	1.987	1.90	1.91	1.90
$N^{\theta}_{\delta_e}$	A_θ	-6.22	-3.95	-3.08	-2.92	-2.82	-2.77	-2.73	-2.86	-2.85	-2.78
	$1/\tau_{\theta_1}$	.012	.011	-.008	-.013	-.010	-.013	.016	-.028	-.011	.043
	$1/\tau_{\theta_2}$	.565	.394	.409	.326	.303	.226	.202	.241	.179	.144

TABLE 2

LATERAL TRANSFER FUNCTION FACTORS

A-7 Data; Stability Axis System; 13,200 ft Altitude

$\alpha°$		10.0	14.0	17.3	18.8	19.8	20.4	20.9	22.1	23.1	24.2
$\beta°$		0	0	0	0	0	0	0	0	0	0
Δ	$1/\tau_s (\zeta_{SR})$	.0312	.0246	.0487	.0959	(.793)	(.082)	(-.400)	-.190	-.160	-.180
	$1/\tau_R (\omega_{SR})$	1.48	1.02	.616	.425	(.256)	(.288)	(.280)	-.457	-.667	-.761
	$\zeta_D (1/\tau_1)$	.130	.179	.255	.333	.480	.787	.900	(.471)	(.387)	(.325)
	$\omega_D (1/\tau_2)$	1.81	1.59	1.12	.848	.615	.567	.616	(.918)	(1.079)	(1.151)
$N^{\phi}_{\delta_A}$	A_ϕ	1.03	.589	.471	.417	.385	.372	.360	.333	.311	.272
	$\zeta_\phi (1/\tau_{\phi_1})$	.146	.143	.194	.267	.434	(-.106)	(-.318)	(-.621)	(-.756)	(-.845)
	$\omega_\phi (1/\tau_{\phi_2})$	1.57	1.26	.795	.538	.318	(.379)	(.589)	(.872)	(.989)	(1.058)
$N^{p}_{\delta_A}$	A_p	1.03	.589	.471	.417	.385	.372	.360	.333	.311	.272
	$1/\tau_{p_1}$	0	0	0	0	0	0	0	0	0	0
	$\zeta_p (1/\tau_{p_2})$	.146	.143	.194	.267	.434	(-.106)	(-.318)	(-.621)	(-.756)	(-.845)
	$\omega_p (1/\tau_{p_3})$	1.57	1.26	.795	.538	.318	(.378)	(.589)	(.872)	(.989)	(1.058)
$N^{r}_{\delta_A}$	A_r	-.0834	-.0940	-.1066	-.110	-.112	-.113	-.112	-.111	-.109	-.103
	$1/\tau_{r_1}$	-1.20	-.953	-.679	-.507	-.344	.309	.460	.632	.687	.705
	$\zeta_r (1/\tau_{r_2})$	.600	.544	.517	.516	.530	-.518	-.487	-.468	-.470	-.477
	$\omega_r (1/\tau_{r_3})$	1.49	1.05	.688	.499	.324	.282	.430	.589	.646	.674
$N^{r}_{\delta_R}$	A_r	-2.328	-1.723	-1.469	-1.395	-1.355	-1.344	-1.331	-1.310	-1.296	-1.286
	$1/\tau_{r_1}$	1.73	1.37	.989	.828	.725	.680	.642	.550	.517	.508
	$\zeta_r (1/\tau_{r_2})$	-.149	-.188	-.213	-.220	-.270	-.227	-.235	-.267	-.320	-.382
	$\omega_r (1/\tau_{r_3})$	.707	.658	.549	.483	.433	.415	.402	.368	.378	.412
$N^{\phi}_{\delta_R}$	A_ϕ	.930	.991	1.000	1.004	1.006	1.005	1.000	.973	.989	.985
	$1/\tau_{\phi_1}$	4.15	2.68	1.70	1.33	1.09	1.01	.948	.789	.779	.839
	$1/\tau_{\phi_2}$	-5.92	-3.63	-2.20	-1.67	-1.36	-1.25	-1.18	-1.00	-.976	-1.028

TABLE 3

LATERAL TRANSFER FUNCTION FACTORS
A-7 Data; Body Axis System; 13,200 ft Altitude

$\alpha°$		10.0	14.0	17.3	18.8	19.8	20.4	20.9	22.1	23.1	24.2
$\beta°$		0	0	0	0	0	0	0	0	0	0
Δ	$1/\tau_S\ (\zeta_{SR})$	.031	.025	.048	.096	(.79)	(.082)	(-.371)	-.190	-.16	-.18
	$1/\tau_R\ (\omega_{SR})$	1.48	1.02	.616	.425	(.256)	(.288)	(.220)	-.457	-.667	-.761
	$\zeta_D\ (1/\tau_1)$	.13	.18	.26	.33	.48	.787	.899	(.471)	(.387)	(.325)
	$\omega_D\ (1/\tau_2)$	1.81	1.59	1.12	.848	.615	.567	.616	(.919)	(1.077)	(1.15)
$N^{\phi}_{\delta_A}$	A_ϕ	1.05	.607	.493	.440	.410	.397	.385	.360	.338	.298
	$\zeta_\phi\ (1/\tau_{\phi_1})$	.146	.143	.194	.267	.434	(-.106)	(-.318)	(-.621)	(-.756)	(-.895)
	$\omega_\phi\ (1/\tau_{\phi_2})$	1.57	1.26	.795	.538	.318	(.378)	(.589)	(.872)	(.989)	(1.058)
$N^{p}_{\delta_A}$	A_p	1.03	.595	.481	.430	.400	.388	.376	.351	.329	.290
	$1/\tau_{p_1}$	-.0154	-.0260	-.0351	-.038	-.034	.367	-.060	-.056	-.059	-.062
	$\zeta_p\ (1/\tau_{p_2})$	.153	.153	.210	.288	.441	.729	(-.263)	(-.550)	(-.672)	(-.747)
	$\omega_p\ (1/\tau_{p_3})$	1.56	1.24	.775	.526	.317	.082	(.570)	(.838)	(.949)	(1.001)
$N^{r}_{\delta_A}$	A_R	.0964	.0511	.0381	.0303	.0251	.0241	.0237	.0227	.0215	.0177
	$1/\tau_{R_1}$	.499	.436	.411	.449	1.013	.241	.295	.309	.301	.291
	$\zeta_R\ (1/\tau_{R_2})$	-.0368	.0550	.219	.407	.552	(-.306)	(-.738)	(-1.468)	(-1.805)	(-2.080)
	$\omega_R\ (1/\tau_{R_3})$	2.14	2.07	1.44	.985	.387	(1.456)	(1.725)	(2.184)	(2.455)	(2.807)
$N^{r}_{\delta_R}$	A_R	-2.13	-1.43	-1.11	-1.00	-.933	-.909	-.887	-.840	-.804	-.768
	$1/\tau_{R_1}$	.758	.565	.471	.439	.421	.406	.390	.358	.326	.298
	$\zeta_R\ (1/\tau_{R_2})$	.457	.407	.345	.320	.306	.292	.276	.224	.152	.072
	$\omega_R\ (1/\tau_{R_3})$	1.11	1.11	.846	.763	.663	.633	.611	.548	.579	.664
$N^{\phi}_{\delta_R}$	A_ϕ	.944	1.022	1.046	1.061	1.069	1.073	1.071	1.072	1.075	1.081
	$1/\tau_{\phi_1}$	4.15	2.68	1.71	1.326	1.09	1.01	.948	.789	.779	.839
	$1/\tau_{\phi_2}$	-5.92	-3.63	-2.20	-1.67	-1.36	-1.25	-1.18	-1.00	-.976	-1.028

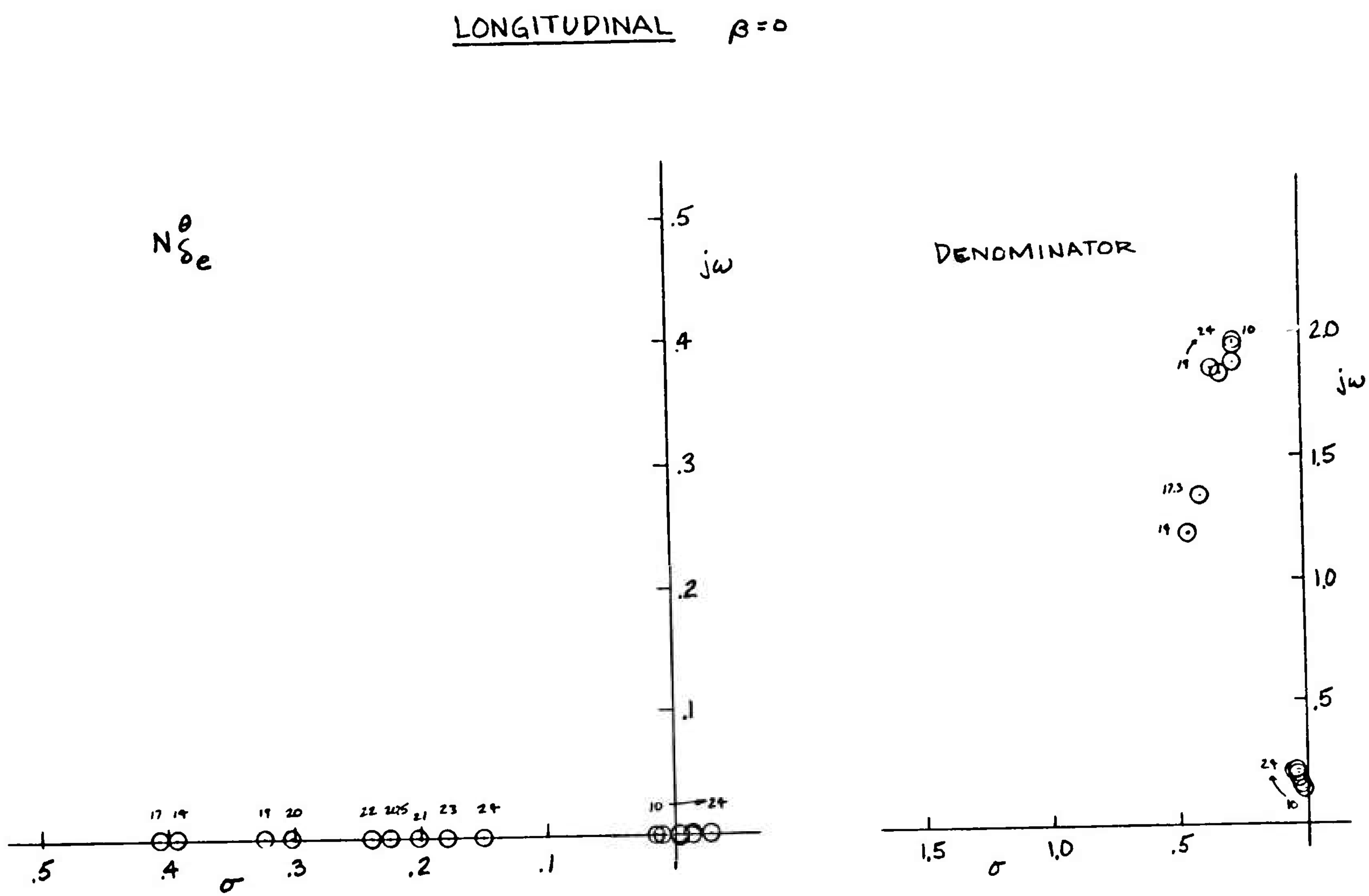


Figure 13. Longitudinal Pole-Zero Loci for Increasing α at 0 deg β

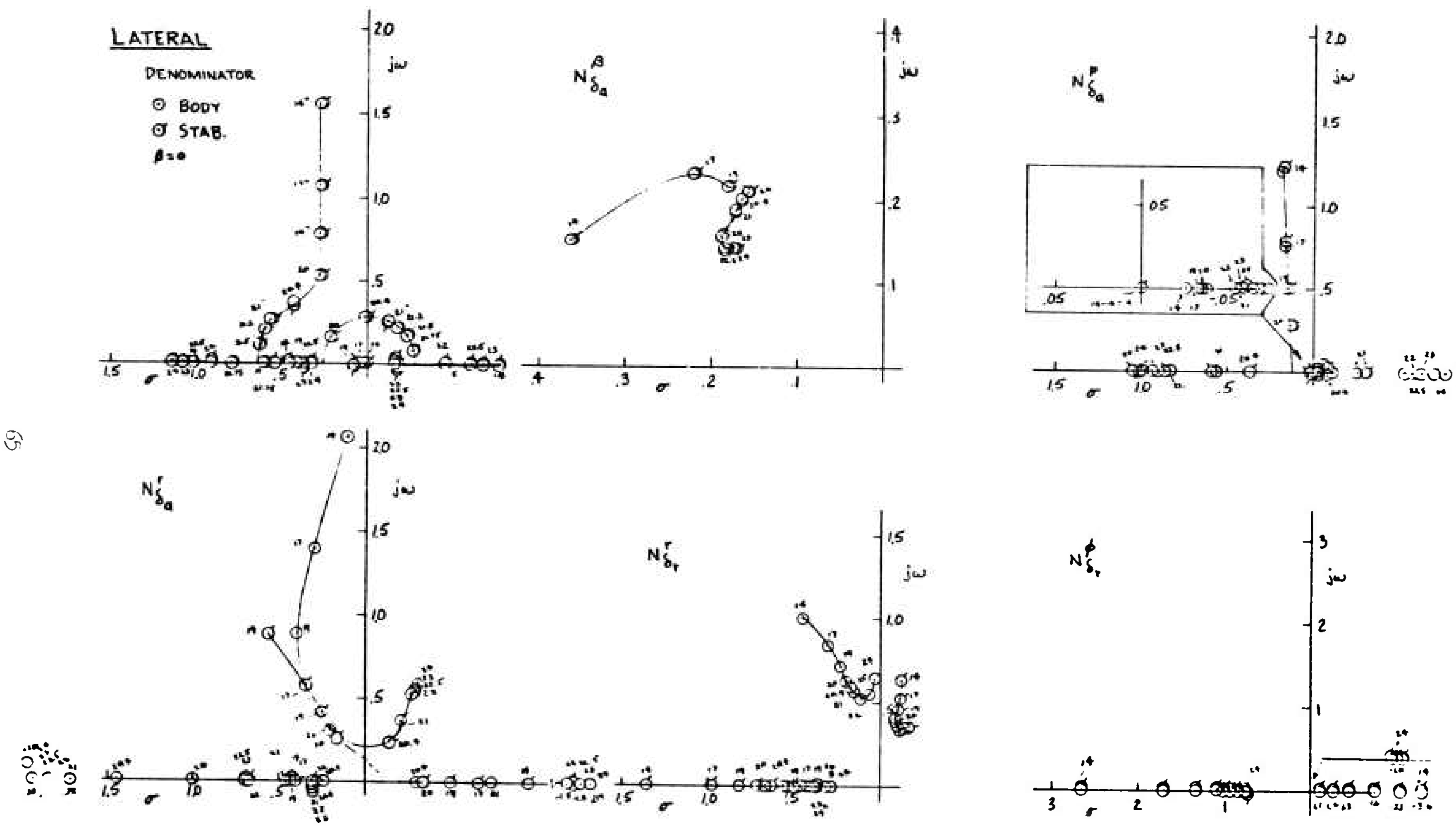


Figure 14. Lateral Pole-Zero Loci for Increasing α at 0 deg β

TABLE 4

$18.8^\circ\alpha_o/6^\circ\beta_o$ COUPLED TRANSFER FUNCTION FACTORS

TRIM CONDITIONS:

α_o = 18.8 deg

β_o = 6 deg

V_{T_o} = 260 fps

T_o = 6152 lb

δ_{e_o} = −12.17 deg

δ_{r_o} = 1.401 deg

δ_{a_o} = 0.839 inch (stick)

φ_o = 0

```
                  1.0000
DENOMINATOR:     (0.0)[.13948;.17535   .024458;.17363]
                 [.65350;.31941   .20285;.23496]
                 [.37116;.86021   .31928;.79876]
                 [.18454;2.0631   .38128;2.0306]<.0093581>


DE    NUMERATORS:

      N(P-DE)    -.29150(0.0)(-.049920)(-1.4200)(1.5996)
                        [.18247;.16619   .030325;.16340]
                        [.11711;5.9322   .69479;5.8914]<-.024852>

      N(Q-DE)    -2.9157(0.0)(-.081840)(-.39324)(.94938)
                        [.38299;.20473   .078411;.18912]
                        [.27816;1.3794   .38370;1.3259]<-.0071046>

      N(R-DE)     .10253(0.0)(.39650)
                        [.18532;.16694   .031022;.16433]
                        [.21713;1.2924   .26107;1.1737]
                        [.11451;6.5935   .75003;6.5501]<.076065>

      N(ALP-DE)  -.055203(0.0)(51.177)
                        [.19809;.16624   .032929;.16294]
                        [.76721;.27239   .20898;.17471]
                        [.31274;1.0654   .33318;1.0119]<-.0067766>
```

TABLE 4. (Continued)

```
N(BET-DE)  -.0037532(0.0)(-.037558)(.62404)(52.759)
                [.18277;.16521   .030379;.16341]
                [.090552;6.2804   .56869;6.2546]
                <.0050570>

  N(V-DE)  -.10256(0.0)(-.12813)(33.750)(-45.993)
              [.80547;.46730   .37639;.27694]
              [.25804;1.1932   .30788;1.1527]<-6.3411>

N(PSI-DE)   .11567(.39558)[.18514;.16676   .030873;.16383]
              [.21765;1.2021   .26164;1.1733]
              [.12161;6.5965   .80219;6.5476]<.089017>

N(THE-DE)  -2.9157(0.0)(-.44902)(.92610)
              [.48990;.19190   .094015;.16730]
              [.26731;1.3735   .36716;1.3235]<.084235>

N(PHI-DE)  -.25431(0.0)(1.6298)(-1.7549)
              [.18353;.16601   .030469;.16319]
              [.11016;5.8304   .64225;5.7949]<.68144>


DA   NUMERATORS:

  N(P-DA)   .43091(0.0)(-.033285)
              [.14653;.16375   .024438;.16495]
              [.38532;.38389   .14811;.35417]
              [.18923;1.3983   .35931;1.3639]<-.0021179>

  N(Q-DA)  -.0034484(0.0)(-.083470)(-45.283)
                [.36498;.13388   .067095;.17120]
                [.39186;.38530   .15098;.35449]
                <-.69352E-4>

  N(R-DA)   .030606(0.0)(.58315)
                [.14056;.16539   .023717;.16424]
                [.42448;.45649   .19377;.41333]
                [.19536;2.5013   .48854;2.4526]<.00064559>

N(ALP-DA)  -.043919(0.0)(-.033747)(.47056)
                [.33703;.17745   .059807;.16707]
                [.39260;.38493   .15112;.35403]<.80756E-5>

N(BET-DA)   .10958(0.0)[.15272;.17506   .026736;.17301]
              [.54752;.31334   .17430;.26638]
              [.21315;1.7141   .36535;1.6747]<.00099991>

  N(V-DA)   1.7706(0.0)(.44061)(-.92750)(1.0819)
              [.31910;.32539   .10402;.30884]<-.083138>

N(PSI-DA)   .032323(.58574)[.13951;.16584   .023137;.16423]
              [.42396;.45672   .19363;.41364]
              [.19595;2.5010   .49017;2.4526]<.00067941>
```

TABLE 4. (Concluded)

```
N(THE-DA)    .15929(0.0)[.46371;.16546   .076729;.14660]
                   [.39140;.38334   .15004;.35276 ]<.00064089>

N(PHI-DA)    .44130(0.0)[.14777;.16616   .024554;.16433]
                   [.37547;.38617   .14501;.35792]
                   [.18662;1.9134   .357071;1.8797]<.0066519>


DR   NUMERATORS:

   N(P-DR)    1.3949(0.0)(-.040621)(1.7693)(-1.8120)
                   [.16736;.16550   .027714;.16326]
                   [.18675;1.9158   .35776;1.8021]<.018299>

   N(Q-DR)   -.013832(0.0)(-.075604)(1.9748)(-2.5026)
                    (-26.394)[.37711;.19614   .073968;.18166
                    <.0052485>

   N(R-DR)   -.90780(0.0)(.39306)
                   [.17123;.16611   .028443;.16365]
                   [.22785;1.1556   .26330;1.1252]
                   [.18529;1.9548   .36221;1.9210]<-.050924>

 N(ALP-DR)   -.10571(0.0)(-.074933)(.46435)(2.0186)(-2.3658)
                   [.55536;.18805   .067013;.17570]
                   <-.00062114>

 N(BET-DR)    .025541(0.0)(-.053866)(.60024)(54.919)
                    [.17141;.16578   .028417;.16333]
                    [.18658;1.9321   .36049;1.8932]<-.051182>

   N(V-DR)    .69796(0.0)(-.34507)(2.7382)(-2.8652)
                   [.34167;.57931   .43759;.31252]
                   [.17106;3.1523   .53931;3.1063]<6.3123>
      DOT
 N(PSI-DR)  -1.0533(.39711)[.17038;.16597   .023279;.16355]
                   [.20892;1.1507   .26456;1.1259]
                   [.18493;1.9548   .36159;1.9210]<-.058833>

 N(THE-DR)    .37436(0.0)(1.9737)(-2.4336)
                   [.43493;.13217   .038184;.15947]<-.061036>

 N(PHI-DR)    1.0561(0.0)(1.9859)(-2.3226)
                   [.16315;.16533   .027810;.16303]
                   [.18769;1.9128   .35911;1.8788]<-.50341>


DE  /DA   COUPLING NUMERATORS:

  N(P-DE/Q-DA)    1.2664(0.0)(.025183)(-.063959)(-.14375)(.49267)
                   [.33851;.39715   .13444;.37370]<.23383E-4>
```

TABLE 5

$19.3^{\circ}\alpha_o/15^{\circ}\beta_o$ TRANSFER FUNCTION FACTORS

TRIM CONDITION: $\alpha_o = 19.3$ deg

$\beta_o = 15$ deg

$V_o = 254$ fps

$\gamma_o = 0$

$\varphi_o = 0$

DENOMINATOR:

```
 1.0000
( .00000    )
(( .32656   , .19913    , .65028E-01, .18822    ))
((-.45863   , .29916    ,-.13720    , .26584    ))
(( .87122   , .61989    , .54006    , .30430    ))
(( .16735   , 2.5332    , .42394    , 2.4975    ))
< .87511E-02>
```

TABLE 5. (Continued)

```
NUMERATOR: P  /DE

 -1.4073
 ( .00000     ) (-.35550E-01) (-.87316    ) ( 1.0271     )
 (( .19167    , .16712    , .32033E-01, .16403    ))
 (( .11801    , 4.7242    , .55752    , 4.6912    ))
 <-.27968E-01>
```

```
NUMERATOR: Q  /DE

 -2.8041
 ( .00000     ) (-.79464E-01) (-.69027    ) ( .99082     )
 (( .41131    , .20561    , .84570E-01, .18741    ))
 (( .23095    , 2.0417    , .47152    , 1.9865    ))
 <-.26856E-01>
```

```
NUMERATOR: R  /DE

  .49242
 ( .00000     ) ( .40231    )
 (( .22191    , .17161    , .38082E-01, .16733    ))
 (( .18607    , 1.0336    , .19232    , 1.0156    ))
 (( .12337    , 4.1882    , .51672    , 4.1562    ))
 < .10934     >
```

```
NUMERATOR: ALP/DE

 -.60083E-01
 ( .00000     ) ( 41.771    )
 (( .36173    , .16176    , .58515E-01, .15081    ))
 (( .76476    , .24809    , .18973    , .15984    ))
 (( .33026    , .99186    , .32757    , .93620    ))
 <-.39764E-02>
```

```
NUMERATOR: BET/DE

 -.11104E-01
 ( .00000     ) (-.51647E-02) ( .51970    ) ( 84.030     )
 (( .20682    , .16915    , .34983E-01, .16549    ))
 (( .12929    , 4.4868    , .58008    , 4.4491    ))
 < .14425E-02>
```

```
NUMERATOR: U  /DE

 -.75574
 ( .00000     ) (-.25897    ) ( 12.728    ) (-13.954     )
 (( .83186    , .54048    , .44961    , .29996    ))
 (( .18114    , 1.7558    , .31804    , 1.7267    ))
 <-31.303     >
```

```
NUMERATOR: PSI/DE

  .52182
 ( .39632     )
 (( .21526    , .17031    , .36661E-01, .16632    ))
 (( .19478    , 1.0330    , .20121    , 1.0132    ))
 (( .12949    , 4.1913    , .54273    , 4.1560    ))
 < .11244     >
```

```
NUMERATOR: THE/DE

 -2.8041
 ( .00000     ) (-.71938    ) ( .98172    )
 (( .54536    , .19230    , .10487    , .16119    ))
 (( .21532    , 2.0310    , .43732    , 1.9833    ))
 < .30208     >
```

```
NUMERATOR: PHI/DE

 -1.2347
 ( .00000     ) (-1.0564    ) ( 1.0804    )
 (( .20059    , .16531    , .33160E-01, .16195    ))
 (( .10939    , 4.7786    , .52273    , 4.7499    ))
 < .81930     >
```

```
NUMERATOR: P  /DA

  .38104
 ( .00000     ) (-.23189E-01)
 ((-.38190E-02, .17199    ,-.65682E-03, .17199    ))
 (( .54362    , .30531    , .16597    , .25626    ))
 (( .19637    , 1.7924    , .35197    , 1.7575    ))
 <-.78275E-04>
```

```
NUMERATOR: Q  /DA

 -.10529E-01
 ( .00000     ) (-.10037    ) (-31.622    )
 (( .52767    , .19233    , .10149    , .16338    ))
 (( .46037    , .28724    , .13223    , .25499    ))
 <-.10199E-03>
```

```
NUMERATOR: R  /DA

  .29332E-01
 ( .00000     ) ( .58695    )
 ((-.47477E-01, .14381    ,-.68278E-02, .14365    ))
 (( .52165    , .23810    , .12421    , .20314    ))
 (( .16108    , 3.7096    , .59756    , 3.6612    ))
 < .27779E-03>
```

```
NUMERATOR: ALP/DA

 -.98950E-01
 ( .00000     ) (-.92319E-01) ( .47994    )
 (( .42511    , .17752    , .75464E-01, .16068    ))
 (( .48037    , .29323    , .14086    , .25719    ))
 < .11880E-04>
```

```
NUMERATOR: BET/DA

  .98367E-01
 ( .00000     )
 (( .29110    , .19652    , .57207E-01, .18801    ))
 ((-.53338    , .54045    ,-.28826    , .45716    ))
 (( .71675    , 1.0383    , .74416    , .72401    ))
 < .11962E-02>
```

```
NUMERATOR: U  /DA

  3.3709
 ( .00000     ) ( .17139    ) (-.65574    ) ( .67794
 (( .46928    , .68538    , .32164    , .60523    ))
 <-.12065     >
```

```
NUMERATOR: PSI/DA

  .31083E-01
 ( .58058     )
 ((-.642[illegible]1E-01, .14277    ,-.91730E-02, .14247    ))
 (( .5248[illegible]    , .23849    , .12517    , .20301    ))
 (( .16227    , 3.7106    , .60213    , 3.6614    ))
 < .28806E-03>
```

```
NUMERATOR: THE/DA

  .14228E-02
 ( .00000     ) ( 239.53    )
 (( .76632    , .13184    , .10103    , .84702E-01))
 (( .46760    , .30662    , .14338    , .27103    ))
 < .55691E-03>
```

```
NUMERATOR: PHI/DA

  .39132
 ( .00000     )
 (( .15974E-01, .16285    , .26013E-02, .16283    ))
 (( .57242    , .30405    , .17404    , .24931    ))
 (( .18345    , 1.8657    , .34226    , 1.8341    ))
 < .33394E-02>
```

TABLE 5. (Continued)

```
NUMERATOR: P   /DR

 1.3697
( .00000     ) (-.34772E-01) (-1.4021     ) ( 1.4103     )
(( .17366    , .16766     , .29115E-01, .16511     ))
(( .17820    , 1.9187     , .34191     , 1.8880     ))
< .97452E-02>


NUMERATOR: Q   /DR

-.44344E-01
( .00000     ) (-.79374E-01) ( 1.6027     ) (-2.0739     )
(-19.371     )
(( .41708    , .20450     , .85295E-01, .18587     ))
< .94775E-02>


NUMERATOR: R   /DR

-.94241
( .00000     ) ( .41666     )
(( .20331    , .17141     , .34850E-01, .16783     ))
(( .23443    , .78150     , .18321     , .75973     ))
(( .16697    , 2.3209     , .38753     , 2.2883     ))
<-.37957E-01>


NUMERATOR: ALP/DR

-.26431
( .00000     ) (-.77908E-01) ( .46826     ) ( 1.6569     )
(-1.9236     )
(( .39281    , .19309     , .75849E-01, .17757     ))
<-.11459E-02>


NUMERATOR: BET/DR

 .24002E-01
( .00000     ) (-.55422E-01) ( .58118     ) ( 56.281     )
(( .23494    , .17152     , .40295E-01, .16671     ))
(( .16819    , 2.1451     , .36077     , 2.1145     ))
<-.58897E-02>


NUMERATOR: U   /DR

 1.6335
( .00000     ) (-.31907     ) ( 2.7731     ) (-2.8980     )
(( .85728    , .52459     , .44972     , .27008     ))
(( .16116    , 3.1885     , .51387     , 3.1468     ))
< 11.718     >


NUMERATOR: PSI/DR

-.99867
( .41035     )
(( .19567    , .17012     , .33288E-01, .16683     ))
(( .24262    , .78184     , .18969     , .75848     ))
(( .16623    , 2.3207     , .39576     , 2.2884     ))
<-.39045E-01>


NUMERATOR: THE/DR

-.12600E-01
( .00000     ) ( 1.6024     ) (-2.0562     ) (-70.339     )
(( .55458    , .18855     , .10456     , .15690     ))
<-.10380     >


NUMERATOR: PHI/DR

 1.0394
( .00000     ) ( 1.1057     ) (-1.9589     )
(( .18231    , .1654      , .30163E-01, .16268     ))
(( .19288    , 1.862      , .35917     , 1.8272     ))
<-.31031     >


NUMERATOR: P   /DE  , Q   /DA

 1.0685
( .00000     ) ( .22112E-01) (-.56633E-01) (-.47681     )
( .83911     )
(( .30870    , .40022     , .12355     , .38067     ))
< .85745E-01>


NUMERATOR: P   /DE  , R   /DA

-.22891
( .00000     ) (-.55913E-02) ( .13024     )
(( .14751    , .7412      , .25684E-01, .17222     ))
(( .12089    , 4.2251     , .51077     , 4.1941     ))
< .90220E-04>


NUMERATOR: P   /DE  , ALP/DA

 .22894E-01
( .00000     ) (-.27319E-01) ( 47.905     )
(( .29405    , .17446     , .51302E-01, .16675     ))
(( .44151    , .28537     , .12599     , .25605     ))
<-.73533E-04>


NUMERATOR: P   /DE  , BET/DA

 .42311E-02
( .00000     ) (-.35135E-0 ) ( 51.052     )
(( .19419    , .16705     , .32440E-01, .16387     ))
(( .14176    , 4.2413     , .60122     , 4.1984     ))
<-.38099E-02>


NUMERATOR: P   /DE  , U   /DA

 .28797
( .00000     ) ( .21229E-01) (-.74457E-01) ( 13.391     )
(-14.587     )
(( .24215    , 1.0898     , .2630      , 1.0574     ))
< .10561     >


NUMERATOR: P   /DE  , PSI/DA

-.24258
(-.52574E-02) ( .12545     )
(( .15950    , .17256     , .27524E-01, .17035     ))
(( .12682    , 4.2275     , .53614     , 4.1934     ))
< .85144E-04>


NUMERATOR: P   /DE  , THE/DA

 1.0685
( .00000     ) (-.12227E-01) (-.52367     ) ( .90584     )
(( .35999    , .40898     , .15132     , .37996     ))
< .92214E-03>


NUMERATOR: P   /DE  , PHI/DA

-.80240E-01
( .00000     ) ( .72702E-01)
(( .29494    , .16331     , .48168E-01, .15605     ))
(( .17482    , 4.2478     , .74260     , 4.1824     ))
<-.28075E-02>


NUMERATOR: Q   /DE  , R   /DA

-.82250E-01
( .00000     ) ( .55636E-01) (-.13868     )
(( .59752    , .22683     , .13553     , .18188     ))
(( .18297    , 3.5945     , .65769     , 3.5338     ))
< .42106E-03>
```

TABLE 5. (Continued)

```
NUMERATOR: Q  /DE  , ALP/DA

 .27683
( .00000    ) (-.10154    )
(( .44569   , .18265    , .81404E-01, .16351    ))
(( .48274   , .29715    , .14344    , .26023    ))
<-.82800E-04>


NUMERATOR: Q  /DE  , BET/DA

-.27595
( .00000    ) (-.81338E-01) (-1.7085    ) ( 2.2298    )
(( .38185   , .20672    , .78936E-01, .19106    ))
<-.36540E-02>


NUMERATOR: Q  /DE  , U  /DA

-.79572E-02
( .00000    ) ( .16322E-01) (-.19676E-01) ( 1154.6    )
(( .10328   , 1.3575    , .14020    , 1.3503    ))
< .54378E-02>


NUMERATOR: Q  /DE  , PSI/DA

-.87160E-01
( .53189E-01) (-.13797    )
(( .60002   , .22721    , .13633    , .18177    ))
(( .18302   , 3.5939    , .65776    , 3.5332    ))
< .42649E-03>


NUMERATOR: Q  /DE  , THE/DA

-.33514E-01
( .00000    ) (-.31264    ) ( .61668    )
(( .27879   , .52950    , .14762    , .50851    ))
< .18116E-02>


NUMERATOR: Q  /DE  , PHI/DA

-1.0973
( .00000    ) ( .00000    ) (-.31264    ) ( .61668    )
(( .27879   , .52950    , .14762    , .50851    ))
< .59315E-01>


NUMERATOR: R  /DE  , ALP/DA

 .17624E-02
( .00000    ) ( 2.6048    ) ( 12.343    )
(( .34422   , .17627    , .60676E-01, .16550    ))
(( .55503   , .39496    , .21921    , .32854    ))
< .27466E-03>


NUMERATOR: R  /DE  , BET/DA

 .32570E-03
( .00000    ) ( .37360    ) ( 233.25    )
(( .21882   , .17140    , .37505E-01, .16724    ))
(( .12214   , 4.2273    , .51633    , 4.1957    ))
< .14900E-01>


NUMERATOR: R  /DE  , U  /DA

 .22167E-01
( .00000    ) ( .44633E-01) ( .55031    ) ( 9.2362    )
(-10.901    )
(( .22103   , 3.0616    , .67671    , 2.9859    ))
<-.51385    >


NUMERATOR: R  /DE  , PSI/DA

-.93312E-03
(-.44169E-01)
(( .73789   , .23733    , .17512    , .16018    ))
(( .17882   , 3.5856    , .64116    , 3.5278    ))
< .29845E-04>


NUMERATOR: R  /DE  , THE/DA

 .82250E-01
( .00000    ) (-.44169E-01)
(( .73789   , .23733    , .17512    , .16018    ))
(( .17882   , 3.5856    , .64116    , 3.5278    ))
<-.26307E-02>


NUMERATOR: R  /DE  , PHI/DA

 .22891
( .00000    ) ( .12181    )
(( .13589   , .16661    , .22641E-01, .16507    ))
(( .12051   , 4.2242    , .50907    , 4.1934    ))
< .13812E-01>


NUMERATOR: ALP/DE  , BET/DA

-.70089E-02
( .00000    ) ( 48.395    )
(( .34468   , .15988    , .55106E-01, .15008    ))
(( .68690   , .25083    , .17229    , .18229    ))
<-.54548E-03>


NUMERATOR: ALP/DE  , U  /DA

-.74780E-01
( .00000    ) ( .39435    ) (-7.6903    ) ( 8.8890    )
(( .46028   , .21971    , .10113    , .19506    ))
< .97316E-01>


NUMERATOR: ALP/DE  , PSI/DA

-.18676E-02
( 2.4295    ) ( 12.515    )
(( .34005   , .17647    , .60007E-01, .16595    ))
(( .55403   , .40043    , .22185    , .33336    ))
<-.28353E-03>


NUMERATOR: ALP/DE  , THE/DA

-.27755
( .00000    )
(( .53181   , .16975    , .90272E-01, .14375    ))
(( .50229   , .28796    , .14464    , .24906    ))
<-.66312E-03>


NUMERATOR: ALP/DE  , PHI/DA

-.23[illegible]12E-01
( .00000    ) ( 47.034    )
(( .28930   , .17436    , .50440E-01, .16699    ))
(( .41888   , .28398    , .11895    , .25786    ))
<-.27110E-02>


NUMERATOR: BET/DE  , U  /DA

 .74340E-01
( .00000    ) (-.44322    ) ( 14.069    ) (-15.851    )
(( .66596   , .76130    , .50699    , .56792    ))
< [illegible].2587    >
```

TABLE 5. (Continued)

```
NUMERATOR: BET/DE , PSI/DA

 -.34515E-03
 ( .36732     ) ( 233.21    )
 (( .21362    , .17022     , .36361E-01, .16529     ))
 (( .12771    , 4.2292     , .54012    ; 4.1945     ))
 <-.15322E-01>


NUMERATOR: BET/DE , THE/DA

  .27582
 ( .00000     ) (-1.7977    ) ( 2.1682    )
 (( .51159    , .19576     , .10015     , .16820     ))
 <-.41190E-01>


NUMERATOR: BET/DE , PHI/DA

 -.43452E-02
 ( .00000     ) ( 55.779    )
 (( .20293    , .16555     , .33596E-01, .16211     ))
 (( .14511    , 4.2438     , .61581     , 4.1989     ))
 <-.11964    >


NUMERATOR: U /DE , PSI/DA

 -.23491E-01
 ( .43199E-01) ( .54193    ) ( 9.2618    ) (-10.884    )
 (( .21563    , 3.0623     , .66033     , 2.9902     ))
 < .51988    >


NUMERATOR: U /DE , THE/DA

 -.10752E-02
 ( .00000     ) ( .12490    ) (-8553.1    )
 (( .12447    , 1.3753   . , .17118     , 1.3646     ))
 < 2.1727    >


NUMERATOR: U /DE , PHI/DA

 -.29574
 ( .00000     ) ( .24404E-02) ( 13.305    ) (-14.491    )
 (( .21570    , 1.1312     , .24399     , 1.1046     ))
 < .17804    >


NUMERATOR: PSI/DE , THE/DA

  .87160E-01
 (-.44169E-01)
 (( .73789    , .23733     , .17512     , .16018     ))
 (( .17882    , 3.5856     , .64116     , 3.5278     ))
 <-.27878E-02>


NUMERATOR: PSI/DE , PHI/DA

  .24258
 ( .11736     )
 (( .15072    , .16569     , .24974E-01, .16380     ))
 (( .12648    , 4.2268     , .53463     , 4.1229     ))
 < .13964E-01>


NUMERATOR: THE/DE , PHI/DA

 -1.0973
 ( .00000     ) (-.31264    ) ( .61668    )
 (( .27879    , .52950     , .14762     , .50851     ))
 < .59315E-01>


NUMERATOR: P /DE , Q /DR

  3.8408
 ( .00000     ) ( .18086E-01) ( .47444    ) ( 1.2581    )
 (-1.3027     )
 ((-.98865    , .84207E-01,-.83252E-01, .12649E-01))
 <-.38300E-03>


NUMERATOR: P /DE , ALP/DR

  .82296E-01
 ( .00000     ) (-.34982E-01) ( 1.4624    ) (-1.4730    )
 ( 46.353     )
 (( .19983    , .16777     , .33525E-01, .16438     ))
 < .80902E-02>


NUMERATOR: P /DE , BET/DR

 -.18569E-01
 ( .00000     ) (-.35099E-01) ( 33.504    )
 (( .19719    , .16753     , .33036E-01, .16424     ))
 (( .93933E-01, 5.3003     , .49787     , 5.2769     ))
 < .17217E-01>


NUMERATOR: P /DE , U /DR

 -1.2637
 ( .00000     ) (-.44393E-01) ( .82866E-01) (-1.7458    )
 ( 1.7693     )
 (( .96214E-01, 13.437     , 1.2928     , 13.374     ))
 <-2.5924    >


NUMERATOR: P /DE , PSI/DR

  .69070
 (-.51282E-02) ( .14434    )
 (( .94970E-01, .17209     , .16344E-01, .17132     ))
 (( .11562    , 5.3227     , .61539     , 5.2870     ))
 <-.42899E-03>


NUMERATOR: P /DE , THE/DR

  3.8408
 ( .00000     ) (-.10615E-01) (-.15254    ) ( .45464    )
 ( 1.2777     ) (-1.2861    )
 <-.46461E-02>


NUMERATOR: P /DE , PHI/DR

  .22847
 ( .00000     ) ( .57273E-01)
 (( .39869    , .18419     , .73434E-01, .16892     ))
 (( .64450E-01, 5.3150     , .34255     , 5.3039     ))
 < .12540E-01>


NUMERATOR: Q /DE , R /DR

  2.6426
 ( .00000     ) ( .46059E-01) (-.77215E-01)
 (( .73540    , .27004     , .19859     , .18299     ))
 (( .24399    , 1.6798     , .40985     , 1.6290     ))
 <-.19339E-02>


NUMERATOR: Q /DE , ALP/DR

  .73848
 ( .00000     ) (-.79373E-01) ( 1.6283    ) (-1.9696    )
 (( .41141    , .20400     , .83929E-01, .18593     ))
 < .78229E-02>
```

TABLE 5. (Concluded)

```
NUMERATOR: Q /DE , BET/DR

 -.67304E-01
 ( .00000    ) (-.79328E-01) ( 56.276    )
 (( .32120   , .20023    , .64315E-01, .18962    ))
 (( .35896   , 1.1708    , .42026    , 1.0927    ))
 < .16512E-01>
```

```
NUMERATOR: Q /DE , U /DR

 -4.5805
 ( .00000    ) (-.80274E-01) ( .12567    ) ( 2.4832    )
 (-2.8332    )
 (( .26704   , 2.5177    , .67234    , 2.4263    ))
 <-2.0606    >
```

```
NUMERATOR: Q /DE , PSI/DR

 2.8004
 ( .43533E-01) (-.77245E-01)
 (( .73768   , .27099    , .19990    , .18296    ))
 (( .24393   , 1.6800    , .40981    , 1.6293    ))
 <-.19518E-02>
```

```
NUMERATOR: Q /DE , THE/DR

 -.89013E-01
 ( .00000    ) (-.75148E-01) ( .41033    ) ( 1.6075    )
 (-1.9488    )
 <-.85982E-02>
```

```
NUMERATOR: Q /DE , PHI/DR

 -2.9145
 ( .00000    ) ( .00000    ) (-.75148E-01) ( .41033    )
 ( 1.6075    ) (-1.9488    )
 <-.28152    >
```

```
NUMERATOR: R /DE , ALP/DR

 -.56623E-01
 ( .00000    ) ( .41287    ) ( 44.111    )
 (( .23035   , .17217    , .39660E-01, .16754    ))
 (( .22707   , 1.0162    , .23075    , .98962    ))
 <-.31564E-01>
```

```
NUMERATOR: R /DE , BET/DR

 .13545E-02
 ( .00000    ) ( .37418    ) (-160.04    )
 (( .21589   , .17088    , .36891E-01, .16685    ))
 (( .16841   , 5.3319    , .89797    , 5.2558    ))
 <-.67333E-01>
```

```
NUMERATOR: R /DE , U /DR

 .92151E-01
 ( .00000    ) ( .96832E-01) ( .46885    )
 (( .17372   , 1.3145    , .22835    , 1.2945    ))
 (( .17885   , 38.372    , 6.8628    , 37.753    ))
 < 10.644    >
```

```
NUMERATOR: R /DE , PSI/DR

 .29980E-01
 (-.22665E-01)
 (( .82989   , .28179    , .23386    , .15722    ))
 (( .22409   , 1.6694    , .37410    , 1.6269    ))
 <-.15037E-03>
```

```
NUMERATOR: R /DE , THE/DR

 -2.6426
 ( .00000    ) (-.22665E-01)
 (( .82989   , .28179    , .23386    , .15722    ))
 (( .22409   , 1.6694    , .37410    , 1.6269    ))
 < .13255E-01>
```

```
NUMERATOR: R /DE , PHI/DR

 -.65179
 ( .00000    ) ( .14098    )
 (( .39769E-01, .15625    , .62141E-02, .15613    ))
 (( .11043   , 5.3125    , .58666    , 5.2800    ))
 <-.63318E-01>
```

```
NUMERATOR: ALP/DE , BET/DR

 -.14421E-02
 ( .00000    ) (-.45526E-01) ( .62398    )
 (( .19302   , .16641    , .32120E-01, .16328    ))
 (( .99633   , 50.255    , 50.070    , 4.3004    ))
 < .20651E-02>
```

```
NUMERATOR: ALP/DE , U /DR

 -.98146E-01
 ( .00000    ) (-.43660    ) (-3.3171    ) ( 3.6067    )
 ( 43.719    )
 (( .83701   , .64842    , .54273    , .35480    ))
 <-9.4234    >
```

```
NUMERATOR: ALP/DE , PSI/DR

 .60003E-01
 ( .40623    ) ( 44.108    )
 (( .22374   , .17099    , .38258E-01, .16665    ))
 (( .23329   , 1.0163    , .23709    , .98823    ))
 < .32465E-01>
```

```
NUMERATOR: ALP/DE , THE/DR

 -.74039
 ( .00000    ) ( 1.6291    ) (-1.9687    )
 (( .54399   , .19111    , .10396    , .16036    ))
 < .86721E-01>
```

```
NUMERATOR: ALP/DE , PHI/DR

 -.62448E-01
 ( .00000    ) ( 1.6183    ) (-1.9535    ) ( 47.056    )
 (( .20753   , .16605    , .34461E-01, .16243    ))
 < .25614    >
```

```
NUMERATOR: BET/DE , U /DR

 -.53687
 ( .00000    ) ( .78205    )
 ((-.13553   , .34656    ,-.46968E-01, .34337    ))
 (( .27491   , 19.451    , 5.3553    , 18.730    ))
 <-19.137    >
```

APPENDIX IV

FIVE DEGREES OF FREEDOM ANALOG SIMULATION

A. SIMULATION DISPLAY AND CONTROLS

The simulation was performed in the Fighter Simulation Laboratory Lear Siegler, Inc., Astronics Division, Santa Monica, California. The equipment used consisted of:

- F104 cockpit, controls, and simulated feel system
- Cockpit panel instruments
- Headup display/outdoor environment scope
- Two EAI PACE 231-R analog computers
- Three brush strip chart 8 channel recorders
- Special purpose interface computer
- Describing Function Analyzer (STI)

The interaction between this equipment is shown in Fig. 15.

The active cockpit panel display includes Attitude Director Indicator, angle of attack, and normal and side acceleration. The headup display/outdoor environment CRT, shown in Fig. 16 gives target and horizon location, and side acceleration indication. Two digital voltmeters were also used to display angle of attack and sideslip to the experimenter at all times and to the pilot when the computer was placed in hold. A rudder pedal shaker provided an indication of incipient stall/departure.

The control system feel characteristics were adjusted to match the A-7 characteristics as closely as possible. The simulator pitch feel system schematic is shown in Fig. 17. The servo motor is nominally used to change the stick trim position or to simulate control system bobweight effects. The servo was not used during this simulation because the normal acceleration effects are negligible in 1 g stalls. The control feel breakouts and gradients used are presented in Figs. 18 through 20.

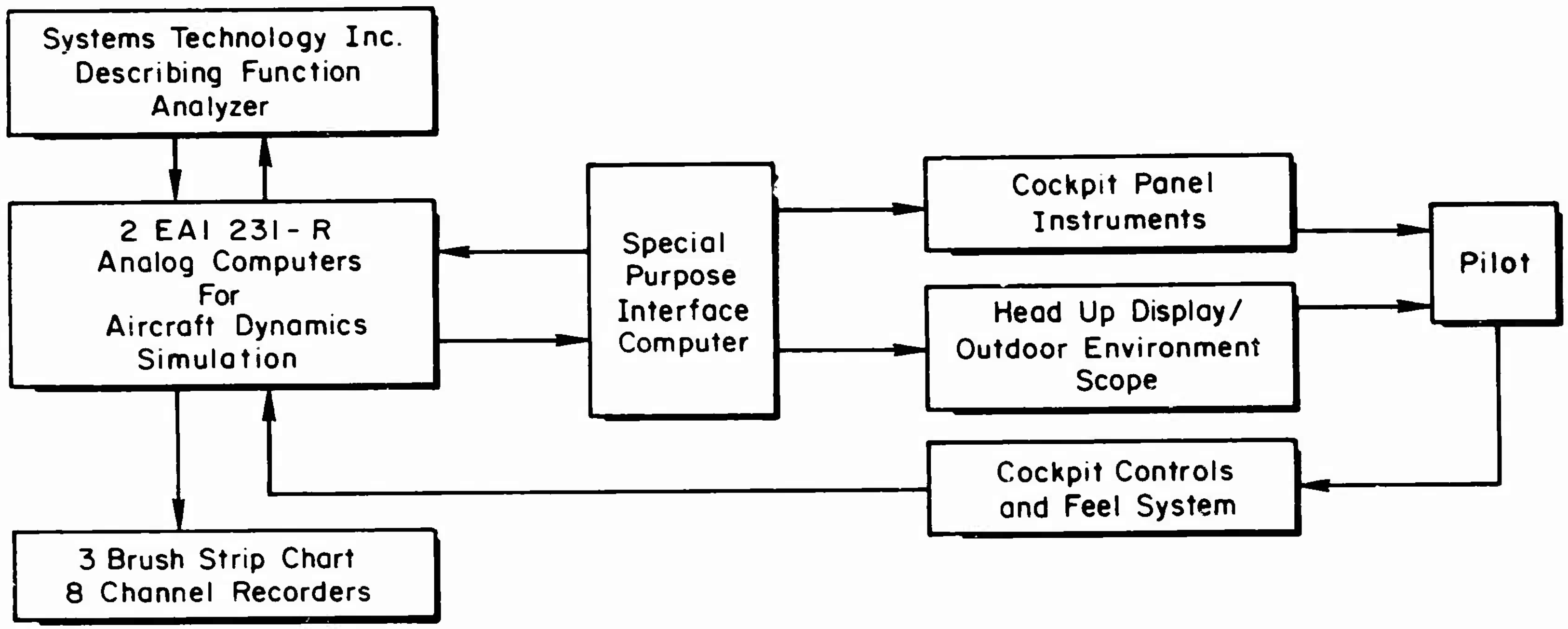


Figure 15. Overall Simulation Flow

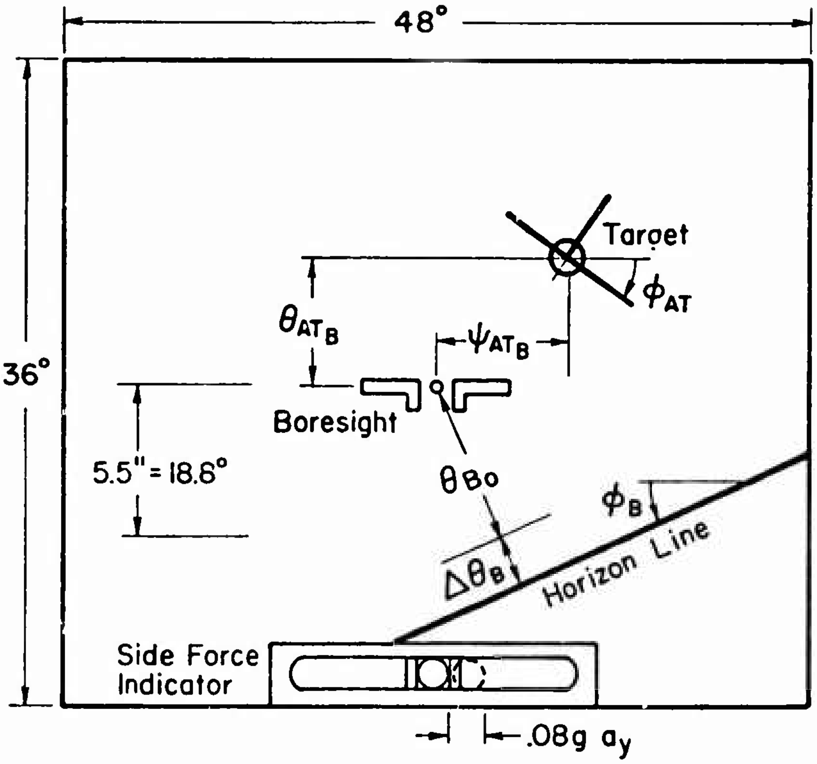


Figure 16. Head-up Display/Outdoor Environment

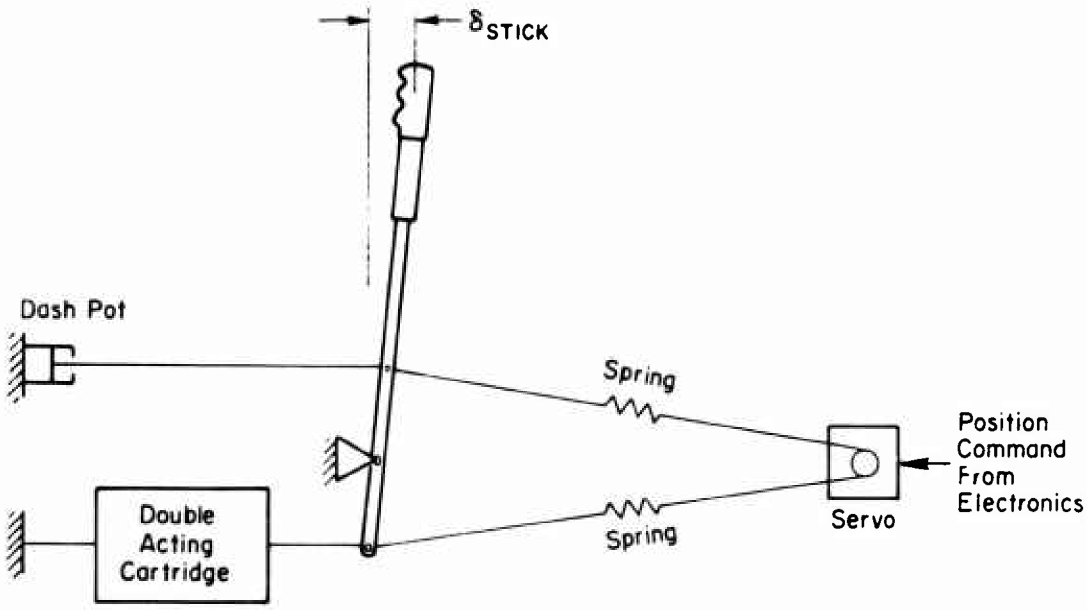


Figure 17. Pitch Feel System Schematic

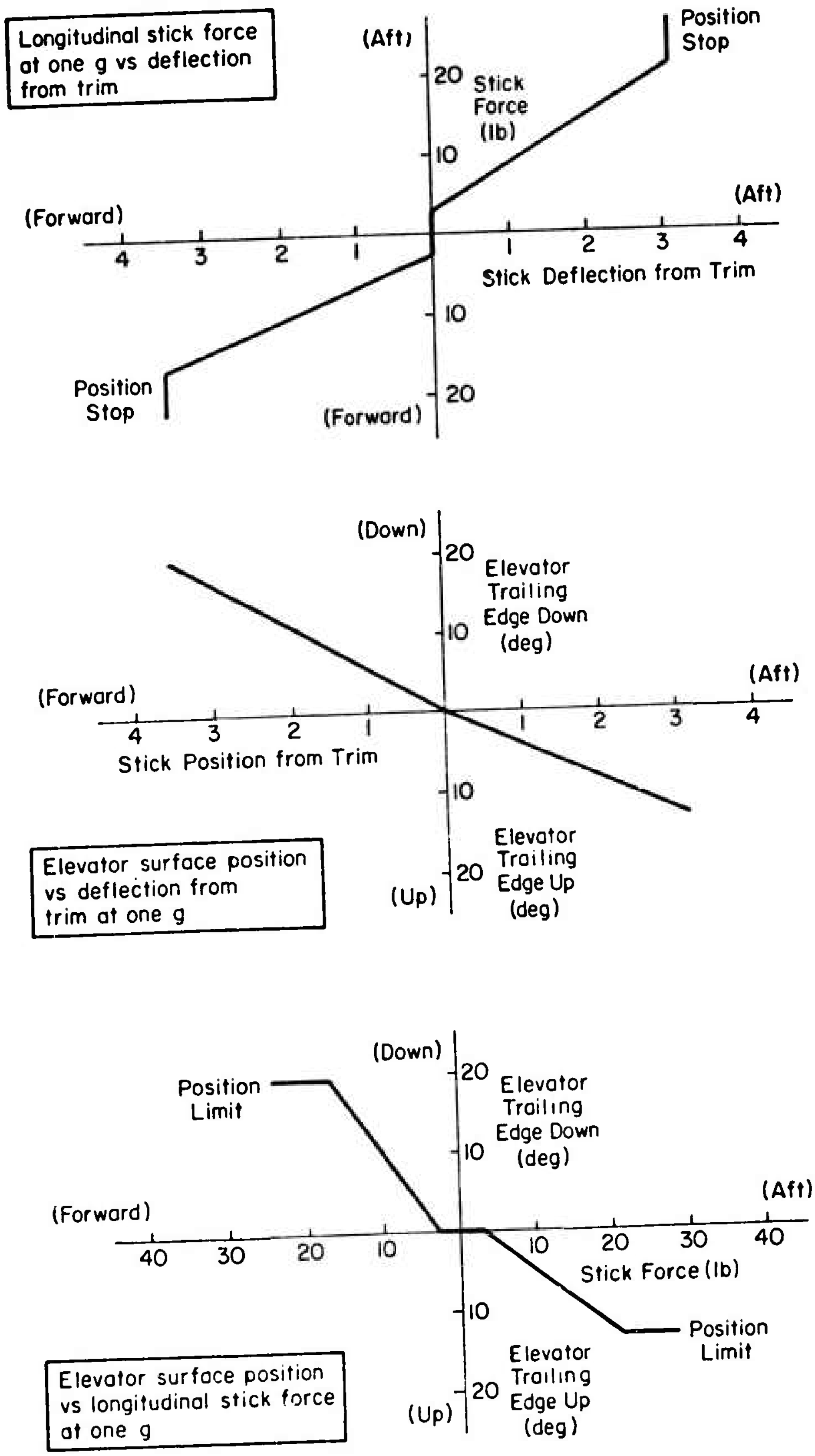


Figure 18. Longitudinal Control Characteristics

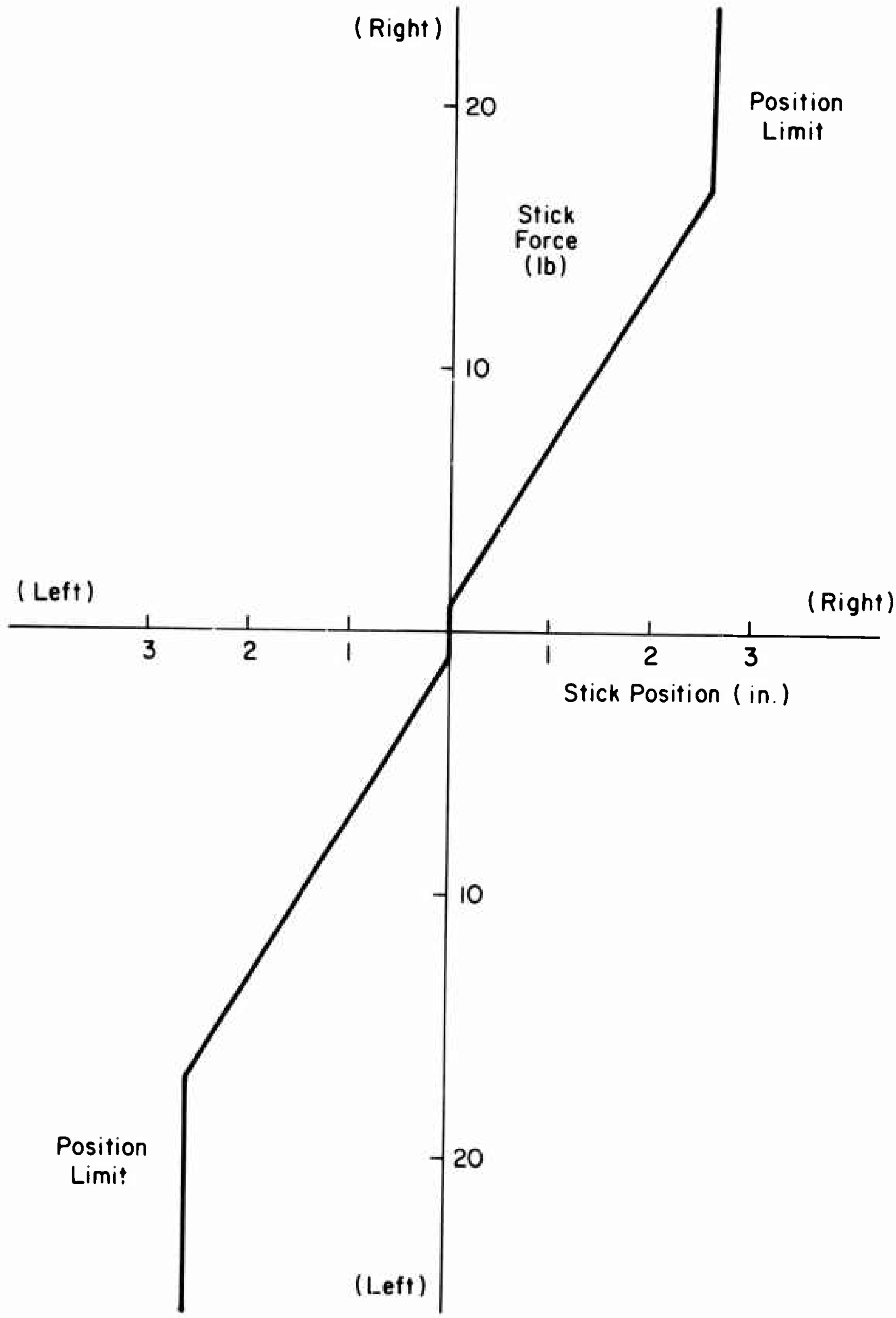


Figure 19. Lateral Stick Force Vs. Position

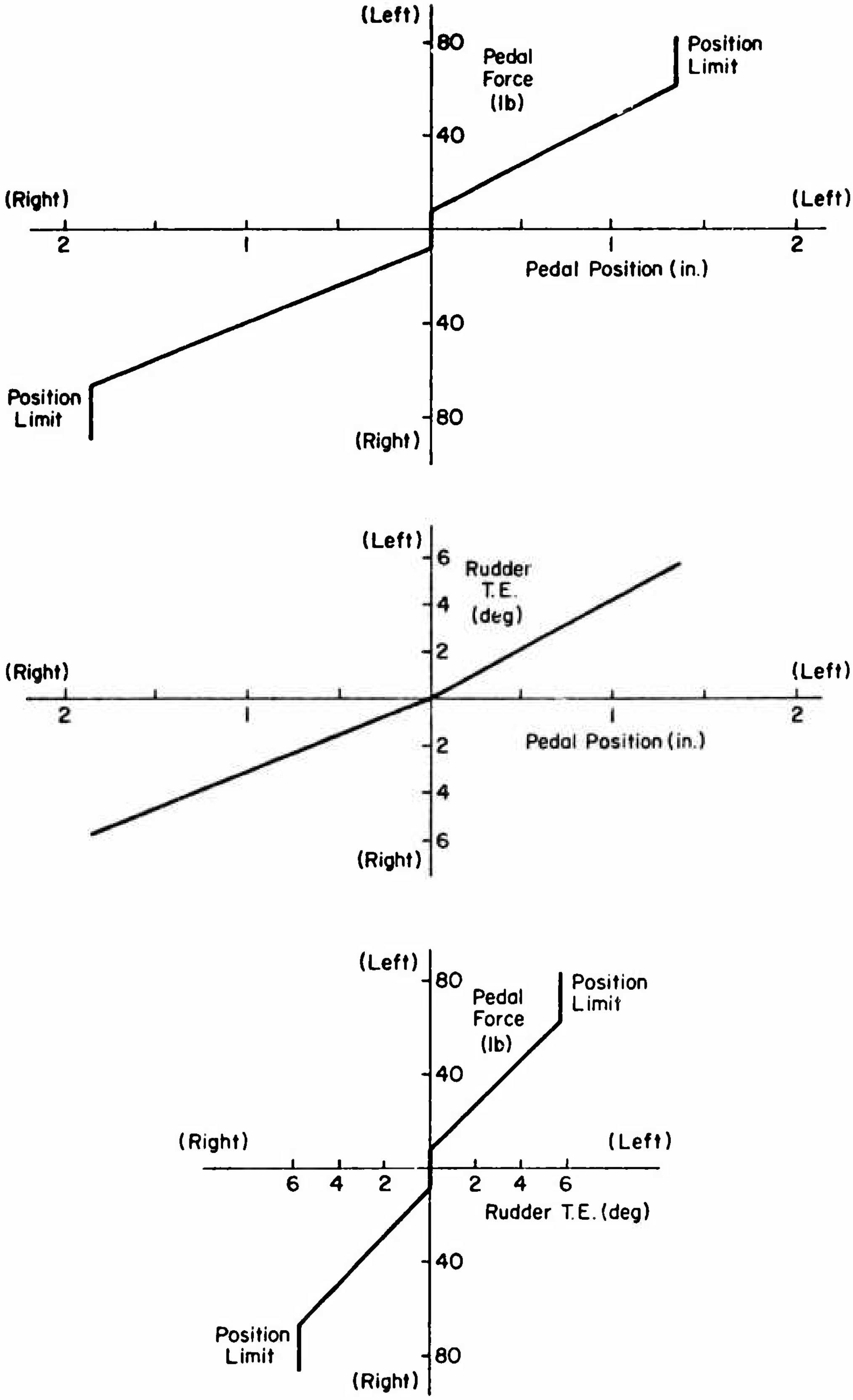


Figure 20. Rudder Pedal Force vs. Position

B. AERODYNAMIC DATA

Thirteen of the A-7 aerodynamic dimensional derivatives showed little variation with angle of attack or sideslip over the range being investigated. Thus fixed values of these derivatives were used throughout the simulation. These are summarized in Table 6.

TABLE 6

NON-SCHEDULED AERODYNAMIC COEFFICIENTS

$\mathcal{L}'_r$	$= 0.3323$	M_Q	$= -0.3865$
$\mathcal{L}_{\delta'_a}$	$= 0.4309$	$M_w U_o$	$= -3.577$
$\mathcal{L}_{\delta'_r}$	$= 1.39$	M_{δ_e}	$= -2.916$
N'_p	$= 0.01927$	Z_w	$= -0.3231$
N'_r	$= -0.1276$	Z_{δ_e}/U_o	$= -0.0569$
$N_{\delta'_a}$	$= 0.03061$	$g \cos \theta_o/U_o$	$= 0.1166$
$N_{\delta'_r}$	$= -0.997$	Y_r	$= 0.02554$

Ten derivatives, $\mathcal{L}'_p$, $\mathcal{L}'_\beta$, $\mathcal{L}'_\alpha$, N'_β, N'_α, Y_v, Y_p, Y_r, Z_p, and Z_r, are linearly scheduled coefficients as functions of α and β or both. All are straight multiplicative functions as shown in Fig. 21 or sine and cosine of α and/or β. As shown, some functions are limited. The coefficients are based on a nominal initial trim condition of 18.8 deg α_o and 6 deg β_o. Since this is a perturbation simulation, the Z equation produces an $\dot{\alpha}$ which integrates to yield a $\Delta\alpha$ and the Y equation of $\Delta\beta$ about the initial trims.

The scheduled aerodynamic coefficients were programmed so that they also could be fixed (or frozen) at an initial trim α_o and β_o condition, because the plant must be restricted to a fixed linear system when taking measures of the pilot describing function characteristics. To facilitate changing initial conditions, linear (frozen) versus nonlinear (unfrozen) aerodynamic characteristics, and changing the aerodynamic coefficients to

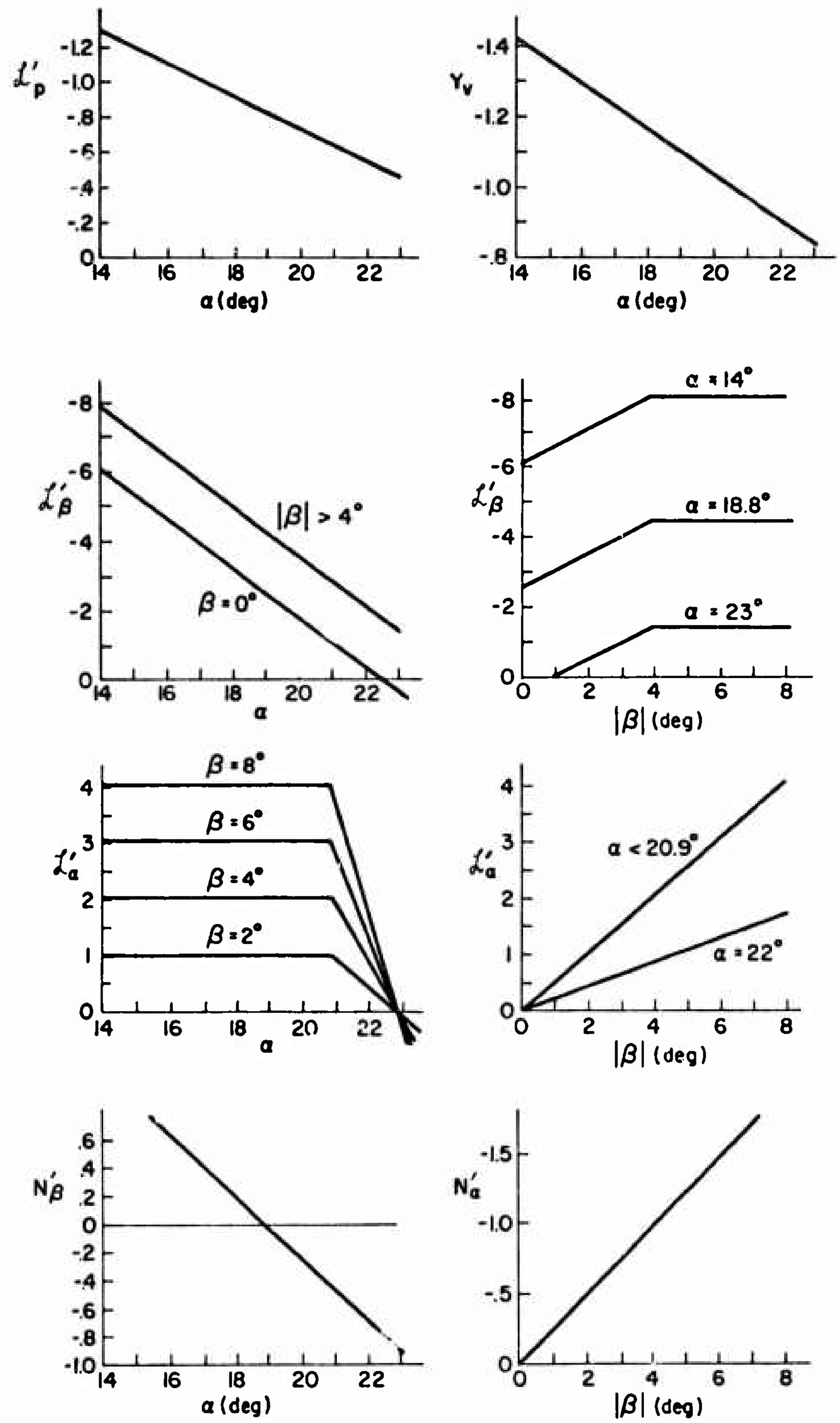


Figure 21. Straight Line Scheduled Aerodynamic Coefficients

reflect modification of the basic airframe, a special (and somewhat complicated) notation was devised for the analog computer program, i.e.,

α_o : 18.8 deg angle of attack about which the aerodynamics are scheduled

β_o : 6 deg sideslip angle about which the aerodynamics are scheduled

$\Delta\alpha_o$: hand set initial condition variation from α_o

$\Delta\beta_o$: hand set initial condition variation from β_o

$\Delta\alpha$: incremental transient angle of attack from the initial condition

$\Delta\beta$: incremental transient sideslip angle from the initial condition

$\Delta\alpha_F$: variation in angle of attack from α_o used to schedule aerodynamic coefficients ($\Delta\alpha_F = \Delta\alpha_o + \Delta\alpha$ for unfrozen aerodynamics, $\Delta\alpha_F = \Delta\alpha_o$ for frozen aerodynamics)

$\Delta\beta_F$: variation in sideslip angle from β_o used to schedule aerodynamic coefficients ($\Delta\beta_F = \Delta\beta_o + \Delta\beta$ for unfrozen aerodynamics, $\Delta\beta_F = \Delta\beta_o$ for frozen aerodynamics)

α_{T_F} : total angle of attack used to generate sine and cosine and special limited functions ($\alpha_{T_F} = \Delta\alpha_F + \alpha_o$)

β_{T_F} : total sideslip angle used to generate sine and cosine and for aerodynamic coefficient scheduling ($\beta_{T_F} = \Delta\beta_F + \beta_o$)

α_T : total transient angle of attack ($\alpha_T = \Delta\alpha_o + \Delta\alpha + \alpha_o$)

β_T : total sideslip angle ($\beta_T = \Delta\beta_o + \Delta\beta + \beta_o$)

Since the aerodynamic coefficient schedules are based on straight line functions representing deviations from α_o and β_o, they consist of terms describing the slope and intercept of the function lines as shown in Table 7. The equations for the coefficients follow. The mechanization diagram is shown in Fig. 22.

As discussed in Volume I, Section IV-B, nine aircraft dynamic configurations were used in the simulation. The method used for configuration changes of scheduled coefficients is detailed in Table 8.

TABLE 7

LINEARLY SCHEDULED COEFFICIENTS

TERM	SLOPE	INTERCEPT
$\mathcal{L}'_p(\alpha)$	$L_{PDA} = 5.3163$	$L_{PAT} = -0.8535$
$\mathcal{L}'_\beta(\alpha)$	$L_{AB} = 43.47$	$L_{KB} = -4.4576$
$\mathcal{L}'_\beta\left(\lvert\beta_{T_{Limited}}\rvert\right)$	$L_{FB} = -25.78$	$L_{KFB} = 1.8$
$\mathcal{L}'_\alpha(\beta)$	$L_{FA} = 29.605$	$L_{KFA} = 3.0996$
$\mathcal{L}'_\alpha(\alpha) = K_{FAC}(\alpha)$	$K_{AC} = -31.833$	$K_{FA} = 2.222$
$N'_\beta(\alpha)$	$N_{AB} = -12.53$	$N_{KAB} = 0$
$N'_\alpha(\beta)$	$N_{FA} = -13.609$	$N_{KFA} = -1.4248$
$Y_v(\alpha)$	$Y_{VB} = 0.3865$	$Y_{KFB} = -0.1111$

Coefficient Equations ($\Delta\alpha_F$ and $\Delta\beta_F$ in Radians)

$$\mathcal{L}'_p = L_{PDA}\Delta\alpha_F + L_{PAT} = 5.3163\,\Delta\alpha_F - 0.8535$$

$$\mathcal{L}'_\beta = L_{AB}\Delta\alpha_F + L_{KB} + L_{FB}\lvert\Delta\beta_F + 0.1047\rvert_L + L_{KFB}$$

$$= 43.47\Delta\alpha_F - 4.4576 - 25.78\lvert\Delta\beta_F + 0.1047\rvert_L + 1.8$$

where $\lvert\Delta\beta_F + 0.1047\rvert_L$ is limited to ≤ 0.06982

and $\Delta\beta_F + 0.1047 = \beta_{T_F}$ in radians

$$\mathcal{L}'_\alpha = K_{FAC}(L_{FA}\Delta\beta_F + L_{KFA})$$

$$= K_{FAC}(29.605\,\Delta\beta_F + 3.0946)$$

where $K_{FAC} = K_{AC}\Delta\alpha_F + K_{FA} = -31.833\,\Delta\alpha_F + 2.222$

is limited to ± 1

$$N'_\beta = N_{AB}\Delta\alpha_F + N_{KAB} = -12.53\,\Delta\alpha_F + 0$$

$$N'_\alpha = N_{FA}\Delta\beta_F + N_{KFA} = -13.609\,\Delta\beta_F - 1.4248$$

$$Y_v = Y_{VB}\Delta\alpha_F + Y_{KFB} = 0.3865\,\Delta\alpha_F - 0.1111$$

$$Y_p = \sin\alpha_{T_F}$$

$$Y_r = -\cos\alpha_{T_F}$$

$$Z_p = -\cos\alpha_{T_F}\sin\beta_{T_F}$$

$$Z_r = -\sin\alpha_{T_F}\sin\beta_{T_F}$$

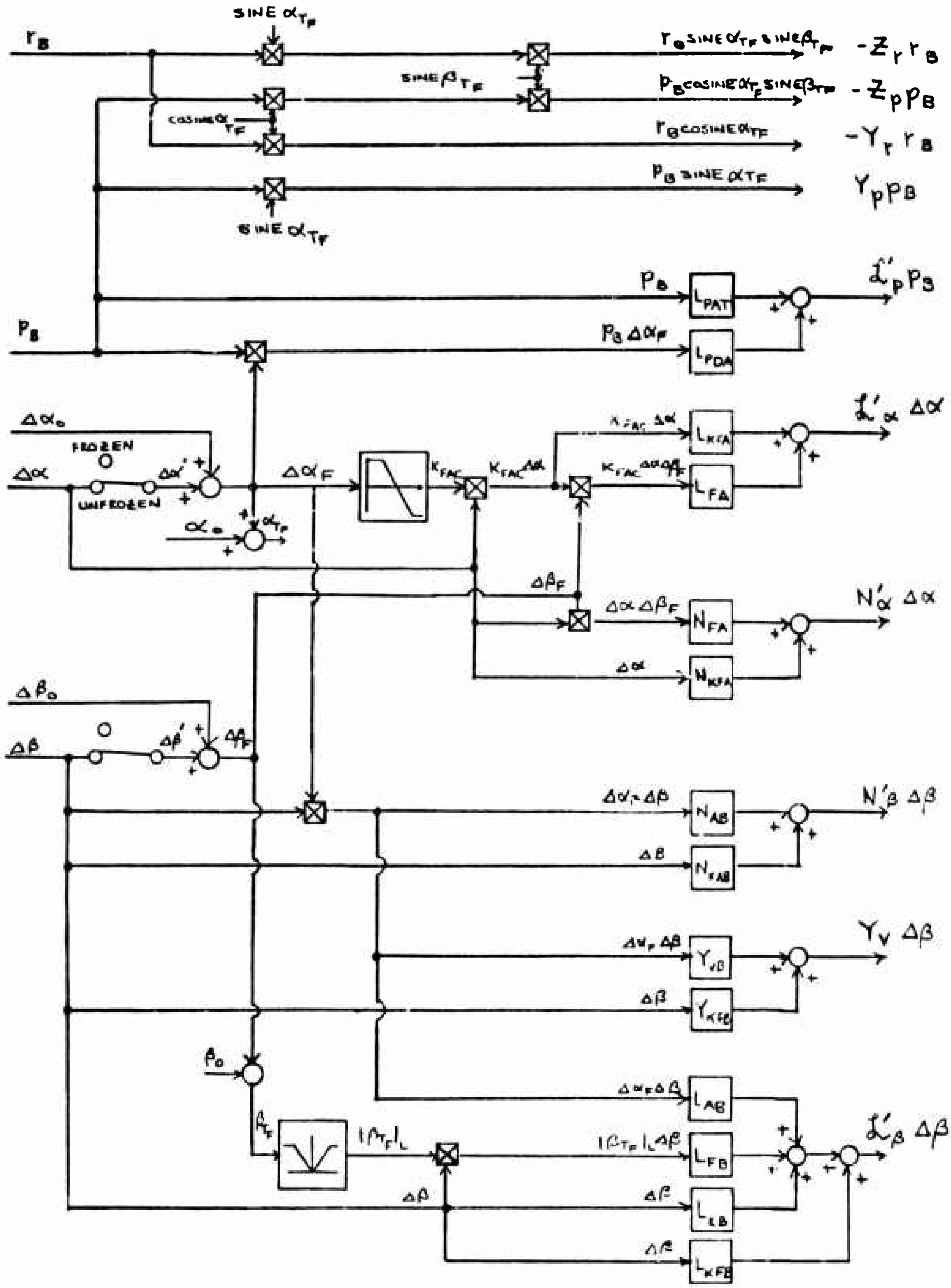


Figure 22. Aerodynamic Coefficient Functions of α and β

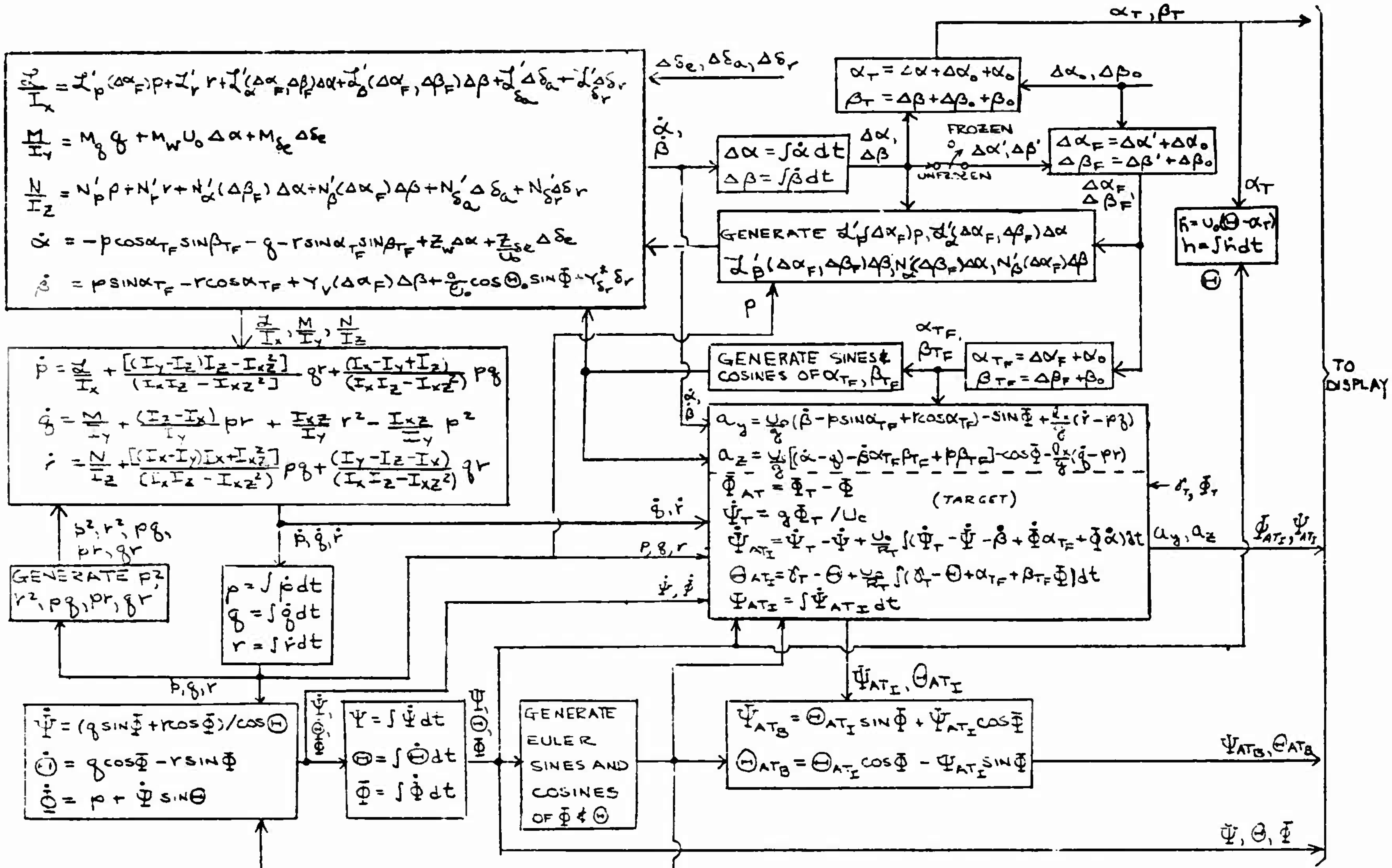
TABLE 8

METHOD USED FOR CONFIGURATION CHANGES OF SCHEDULED COEFFICIENTS

CONFIG-URATION	$\mathcal{L}'_\alpha$		$\mathcal{L}'_\beta$	N'_α		N'_β	$\mathcal{L}'_p$
	SLOPE L_{FA} =50Q16	INTERCEPT L_{KFA} =25P17	INTERCEPT L_{KB} =-10Q18	SLOPE N_{FA} =-40Q25	INTERCEPT N_{KFA} =-10P26	INTERCEPT N_{KAB} =±4Q27 (FS10)	INTERCEPT L_{PAT} =-Q15
1	29.605	3.0996	-4.4576	-13.609	-1.4248	0.(CENTER)	.8535
2				-30.534	-3.1969		
3						.3(LEFT)	
4				-5.725	-.5994	0.(CENTER)	
5			-6.0000				
6			-2.2000				
7	14.320	1.5000					
8	29.605	3.0996				.5(RIGHT)	
9			-4.4576	-13.609	-1.4248	.4(LEFT)	.4000

C. EQUATIONS AND DIAGRAMS

The five degrees-of-freedom aircraft and display system equation flow diagram is shown in Fig. 23. This is followed by the patching diagrams, scale factor, and pot set tables.



NOTE: FOR ANALOG SIMULATION IT IS ASSUMED TAN β = SIN β

Figure 23. Aircraft and Display System Equation Flow Diagram

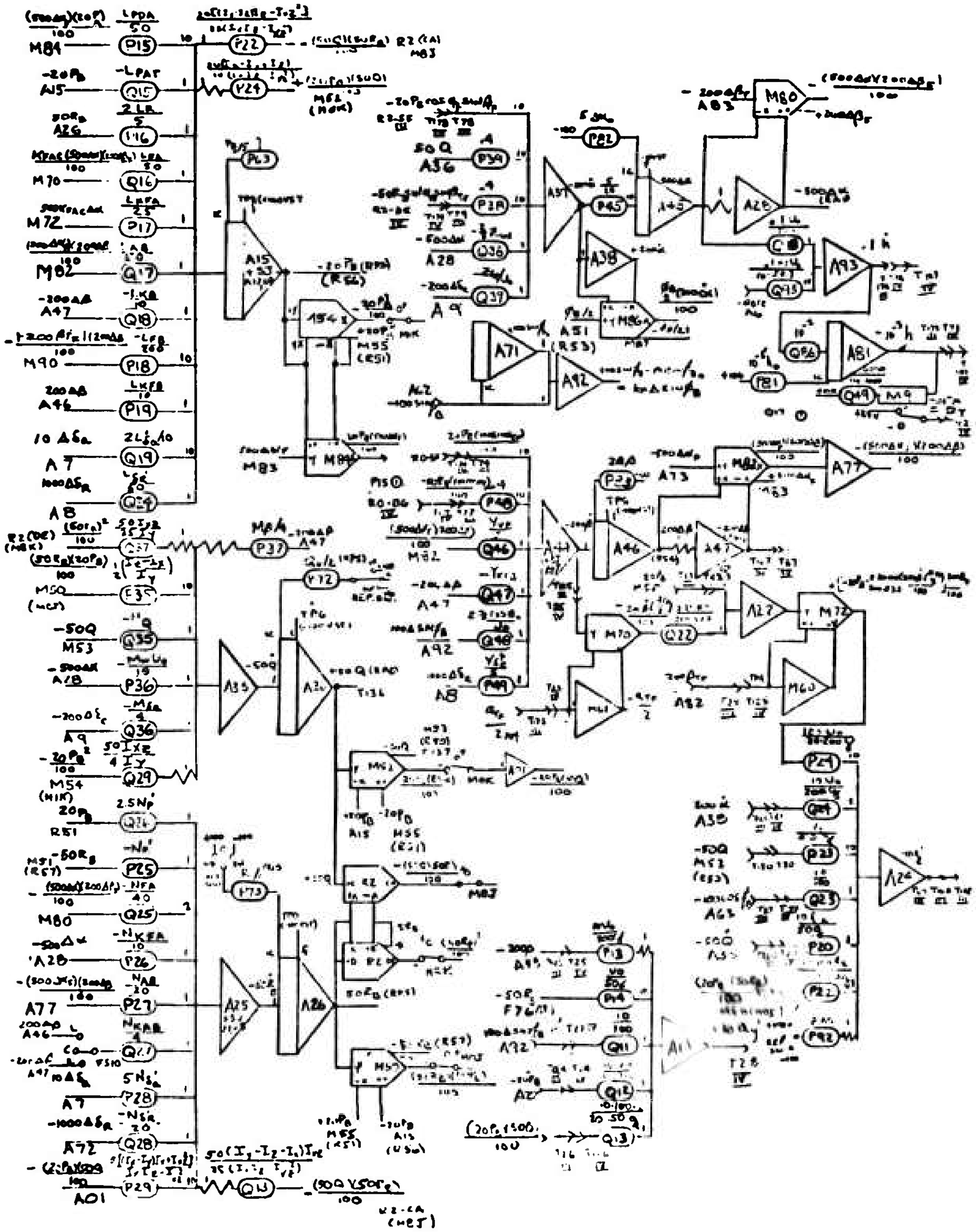


Figure 24. Aerodynamics

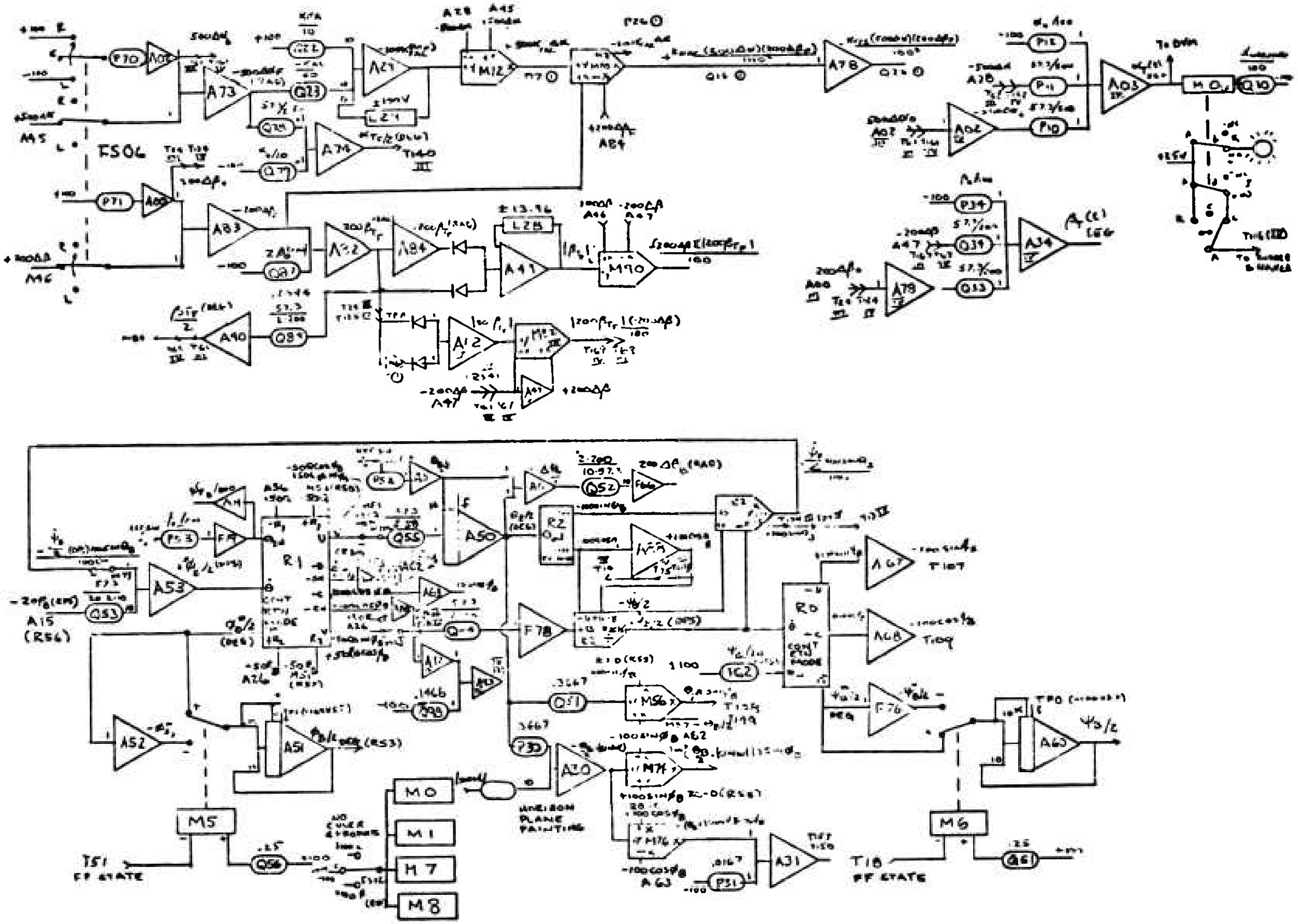


Figure 25. α and ε Multiplicative Body Resolutions

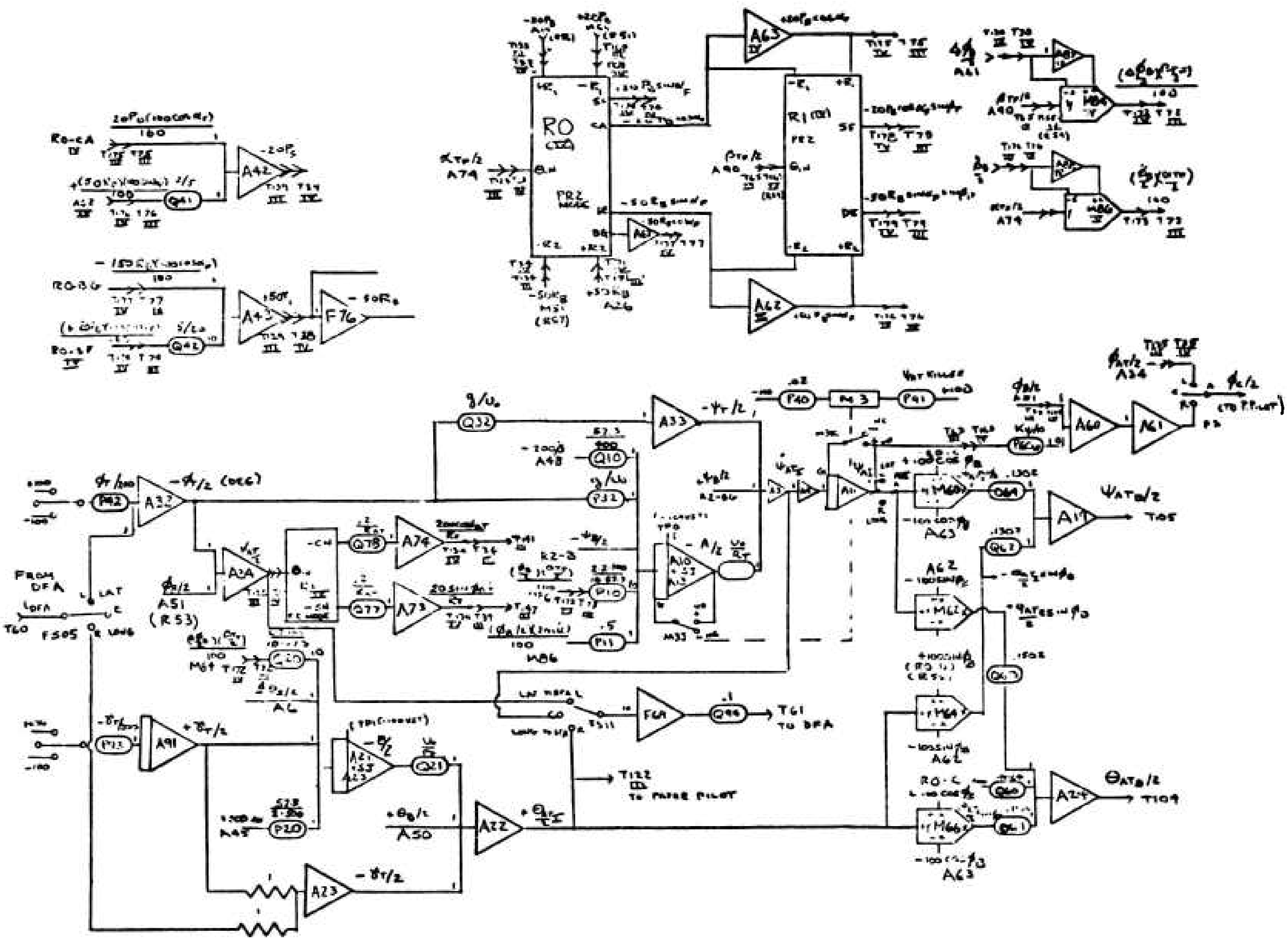


Figure 26. α and β and Target Resolutions

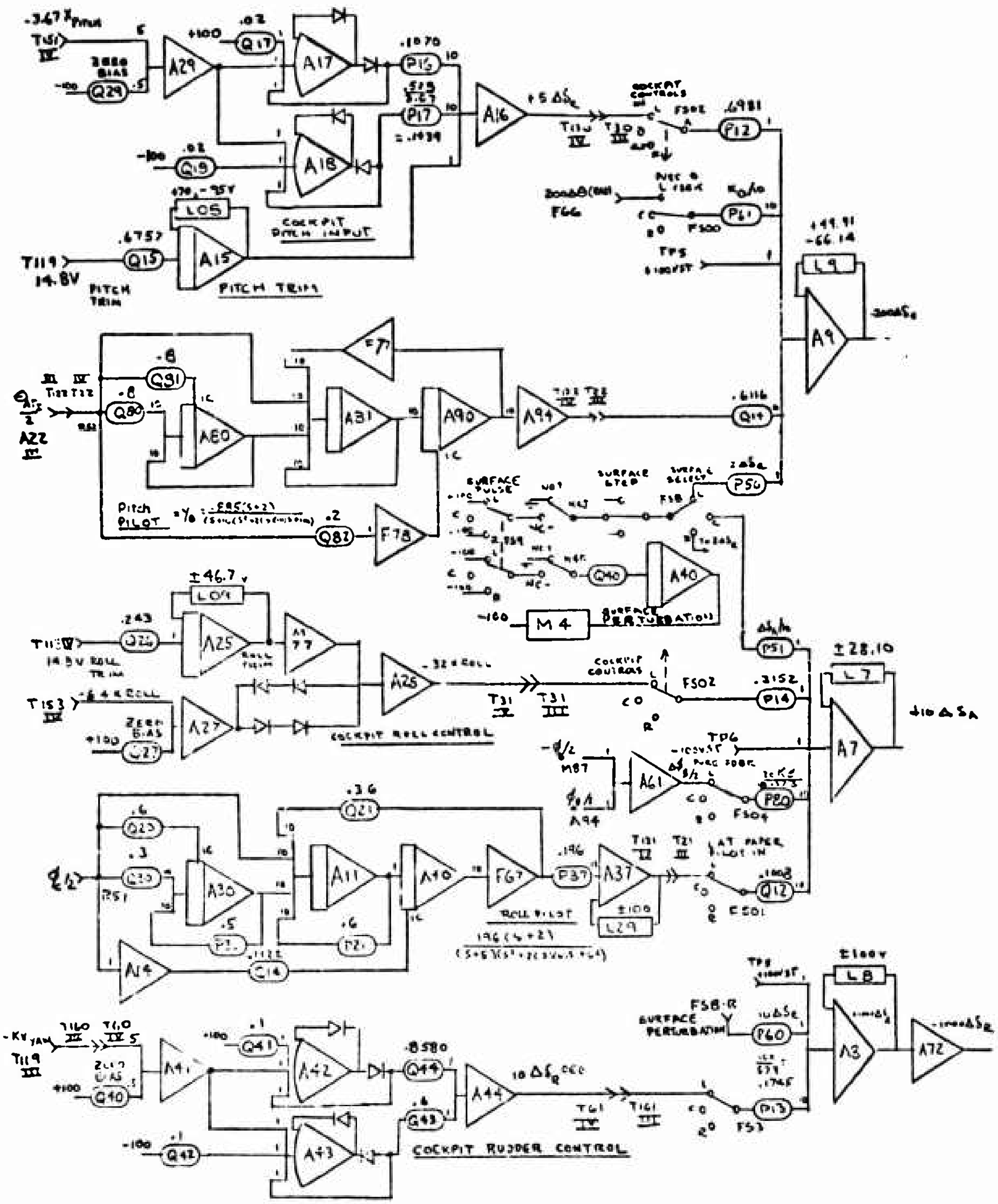


Figure 27. Surface Controls

Maximum Values

$\dot{p} = 5\ RPS^2$	$\dot{r} = 2\ RPS^2$
$p = 5\ RPS$	$r = 2\ RPS$
$\varphi = \pm 180\ deg$	$\psi = \pm 180\ deg$
$\dot{q} = 2\ RPS^2$	$\Delta\alpha = \pm 0.2\ rad$
$q = 2\ RPS$	$\dot{\alpha} = \pm 0.5\ RPS$
$\theta = \pm 180\ deg$	$\Delta\beta = \pm 0.5\ rad$
$\dot{h} = 20\ FPS$	$\dot{\beta} = \pm 0.5\ rad$

$\Delta\delta_e = (+7\ deg \rightarrow -26.5\ deg)\ \pm 0.5\ rad$

$\Delta\delta_a = \pm 10$ in. stick (± 3.75 in. actual)

$\Delta\delta_r = \pm 6\ deg = \pm 0.1\ rad$ (2.75 in. actual)

Scale Factors

$\dot{p} = 20\ v/RPS^2$	$\dot{r} = 50\ v/RPS^2$
$p = 20\ v/RPS$	$r = 50\ v/RPS$
$\varphi = 0.5\ v/deg = 20\ v/rad$	$\psi = 0.5\ v/deg = 20\ v/rad$
$\dot{q} = 50\ v/RPS^2$	$\dot{\alpha} = 200\ v/RPS$
$q = 50\ v/RPS$	$\Delta\alpha = 500\ v/rad$
$\theta = 0.5\ v/deg = 20\ v/rad$	$\dot{\beta} = 200\ v/RPS$
$\Delta\delta_e = 200\ v/rad$	$\Delta\beta = 200\ v/rad$
$\Delta\delta_a = 10\ v/in.$	$\lvert\Delta\beta + 0.1047\rvert_L = 100\ v/rad$
$\Delta\delta_r = 1000\ v/rad$	

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PROBLEM H10X 1033
BY JRH

DATE 10/12/73
COMPUTER III

PAGE	P-SERIES DESCRIPTION	SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
			00			
			01			
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			09			
3	2·100/10·57.3	.3490	10	.1433	57.3/400	3
3	1/2	.5000	11	.13.00	U_0/R_{AT}	3
4	PITCH STICK GAIN	.6981	12	.1008	[illegible] PILOT GAIN	4
4	RUDDER GAIN	.1745	13	.1748	[illegible] PITCH PAPER	1
4	ROLL STICK GAIN	.3152	14	.6116	PILOT	4
1	$L_{PDA}/50 (L'_p(\alpha))$	.1063	15	.8535	$-L_{PAT} (L'_P)$	1
1	$2L_R/5$	.1329	16	.5921	$L_{FA}/50 (L'_\alpha(\beta))$	1
1	$L_{KFA}/25 (L'_\alpha(\alpha))$	.1240	17	.8693	$L_{AB}/50 (L_{\dot{\beta}}(\dot{\beta}))$	1
1	$-L_{FB}/200 (L'_\beta(\beta))$	.1289	18	.4458	$-L_{KB}/10 (L'_\beta)$	1
1	$L_{KFB}/10 (L'_\beta)$	.1800	19	.0843	$2L'_{\delta a}/10$	1
3	57.3/2·500	.0573	20	.3490	2·100/10·57.3	3
			21	.13.00	U_0/R_{AT}	3
1	[illegible]	.5210	22	.2222	$K_{CA}/10$	2
1	RUDDER GAIN	.1745	23	.6367	$-K_{AC}/K_G$	2
1	[illegible]	.1745	24	.6279	$L_{\delta R}/60$	1

PAGE	P-SERIES DESCRIPTION	SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
1	$-N_R$	.1276	25	.3402	$-N_{FA}/10 (N'_\alpha(\beta))$	1
1	$-N_{K\dot{\beta}}/10 (N'_{\dot{\beta}})$	.1425	26	.0982	$5N'_p/2$	1
1	$-N_{AB}/20 (N'_\beta(\alpha))$	.6265	27	-0-	$N_{KAB}/4 (N'_\beta)$	1
1	$5N'_{\delta a}$	.1530	28	.0500	$-N_{\delta R}/20$	1
1	[illegible]	.3151	29	.7699	$-50I_{xz}/4I_Y$	
2	HORIZON SCALING	.3667	30			
2	HORIZON BIAS	.0167	31			
3	g/U_0	.1238	32	.1238	g/U_0	3
			33			
			34			
1	$\frac{1}{2}(I_z-I_x)/I_y$	.4521	35	.3865	$-M_q$	1
1	$-M_wU_0/10$	.3577	36	.7289	$-M_{\delta e}/4$	1
1	$-M_{\dot{\alpha}}/4$	-0-	37	.1232	$50I_{xz}/25I_Y$	1
1	4/10	.4000	38	.1292	$(-2/5)Z_w$	1
1	4/10	.4000	39	.0569	$-Z_{\delta e}/U_0$	1
3	$\dot{\psi}_{ATE}$ & $\dot{\theta}_{ATE}$ KILLER COMP.	.0200	40			
			41	.4000	2/5	
			42	.2500	5/20	3
			43			
			44			
1	5/20	.2500	45			
			46	.0773	$Y_{VB}/5 (Y_v(\beta))$	1
			47	.1111	$-Y_{KFB} (Y_v)$	1
1	.4	.4000	48	.2333	[illegible]	1
1	$Y_{\delta R}^*/5$	.0051	49	.0000	$6 \times 10^3/10^2 \cdot 10^3$	1

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PAGE	P-SERIES DESCRIPTION	SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
4	$2\Delta\delta_e$ (RAD)	—	50			
4	$\Delta\delta_a/10$ (IN)	—	51	.3667	HORIZON SCALING	
2	$\Theta_{B_0}/200$ (DEG)	.0990	52	.6981	2·200/57.3·10	4
2	$\phi_{B_0}/200$ (DEG)	-0-	53	.1433	57.3/20·2·10	2
			54			
			55	.5730	57.3/2·50	2
			56	.2500	ϕ_B^n COMP. POT	2
			57			
			58			
			59			
4	$10\Delta\delta_r$ (RAD)	—	60	.0064	ΘAT & BIAS	3
4	$K_{\dot{\phi}}/10$	.1000	61	.1520	ΘATB SCALING	3
			62	.1302	ΨATB "	3
1	$P_{B_0}/5$		63	.1520	ΘATB "	3
			64	.1302	ΨATB "	3
			65			
			66			
			67			
			68			
			69	.2500	Ψ_B^n COMP. POT	2
2	$5\Delta\alpha_F$ (RAD)		70			
2	$2\Delta\beta_F$ (RAD)		71			
1	$Q_0/2$		72			1
1	$R_{B_0}/2$		73			1
			74			

PAGE	P-SERIES DESCRIPTION	SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
			75			
			76			
			77			
			78	.5730	57.3/2·50	2
			79	.9400	$\alpha_0/20$ (DEG)	2
4	$2.0K_{\phi}/57.3$	—	80			
1	$10^{-5}h_0$	.1320	81			
1	$5\Delta\alpha_0$		82			
1	$2\Delta\beta_0$		83			
			84	.5730	57.3/2·50	2
			85	.3000	.300 SERVO EQUALIZER REF	2
			86	.0100	10^{-2}	2
			87	.2057	$\beta_0/20$ (RAD)	2
			88			
			89	.1433	57.3/2·200	2
			90			
3	ψ_{AT} & ψ_{AT} ELEC CONT.	—	91			
3	$\phi_T/200$ (DEG)	—	92			
3	$\theta_T/200$ (DEG)	—	93	.0908	.2(.26)/10·57.3	1
			94	.1000	DFA SCALING	3
			95			
			96			
			97			
			98	.0520	.1(260)/500	1
			99			

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			07			
			08			
			09			
2	57.3/500	.1146	10	.2130	α WARNING/100	2
2	α_0/100	.1880	11	.1000	10/100	1
2	57.3/500	.1146	12	.0971	$10\ell_x/50U_0$	1
1	$10U_0/200g$	.4037	13	.4857	$10\cdot100\ell_x/20\cdot50g$	1
1	$U_0/50g$	.1615	14	.1122	ROLL ANALOG PILOT	4
			15	.6757	.6757 PITCH STICK GAIN	4
4	.1070	.1070	16			
4	.528/5.67	.1439	17	.0200	.02 PITCH STICK GAINS	4
			18	.0200	.02	4
			19			
1	$10\ell_x/50g$	.0971	20	.6000	ROLL PAPER PILOT	4
4	ROLL ANALOG PILOT	.6000	21			
1	$10\cdot100\ell_x/20\cdot50g$	.4857	22	.3490	$2\cdot20\cdot10\tau/200\cdot57.3$	1
1	$U_0/50g$	.1615	23	.1000	10/100	1
1	$100U_0/20\cdot200g$	.2019	24	.4037	$10U_0/200g$	1

PAGE	P-SERIES DESCRIPTION	P-SERIES SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
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			26	.243	ROLL STICK GAIN	4
			27	--	ROLL STICK ZERO BIAS	4
			28			
			29	—	PITCH ZERO BIAS	4
4	ROLL P. PILOT	.5000	30	.3000	ROLL ANALOG PILOT	4
			31			
			32			
			33	.2865	57.3/200	2
2	β_0/100	.0600	34	.2865	57.3/200	2
			35			
			36			
4	ROLL PAPER PILOT	.1960	37			
			38			
			39			
			40	—	RUDDER ZERO BIAS	4
			41	.1000	RUDDER GAIN	4
			42	.1000	"	4
			43	.6000	"	4
			44	.8580	"	4
			45			
			46			
			47			
			48			
			49			

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PAGE	P-SERIES DESCRIPTION	P-SERIES SET	POT NO.	Q-SERIES SET	Q-SERIES DESCRIPTION	PAGE
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			53			
			54			
			55			
			56			
			57			
			58			
			59			
3	4/10	.4000	60			
			61			
			62			
			63			
			64			
			65			
			66			
			67			
			68			
			69			
			70			
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			72			
			73			
			74			

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			76			
			77	.3175	^{2}/RAT TARGET SIZE	3
			78	.3175	^{2}/RAT TARGET SIZE	3
			79			
			80	.8000	[illegible] ANALOG PILOT	
			81	.8000	" " "	
			82	.2000	" " "	
			83			
			84			
			85			
			86			
			87			
			88			
			89			
			90			
			91			
1	Q2 BIAS	—	92			
			93			
			94			
			95			
			96			
			97			
			98	—	HORIZON BIAS	2
			99			

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APPENDIX V

TIME RESPONSES TO STEP INPUTS

This appendix contains response time traces (Fig. 28-43) of the five degrees of freedom aircraft with nonlinear aerodynamics for step elevator, aileron, and rudder inputs for the nine dynamic configurations employed in the analog flying qualities simulation as described in Appendix IV. The simulation started at an initial condition of $18.8^{\circ}\alpha_0/3^{\circ}\beta_0$ in each case. The sequence of presentation is:

Lateral responses to step elevator

Lateral responses to step aileron

Lateral responses to step rudder

Longitudinal responses to step elevator

Longitudinal responses for step aileron and rudder are not shown because the coupling from lateral motion into longitudinal motion is insignificant.

Time responses for Configuration 7 are the same as for Configuration 6.

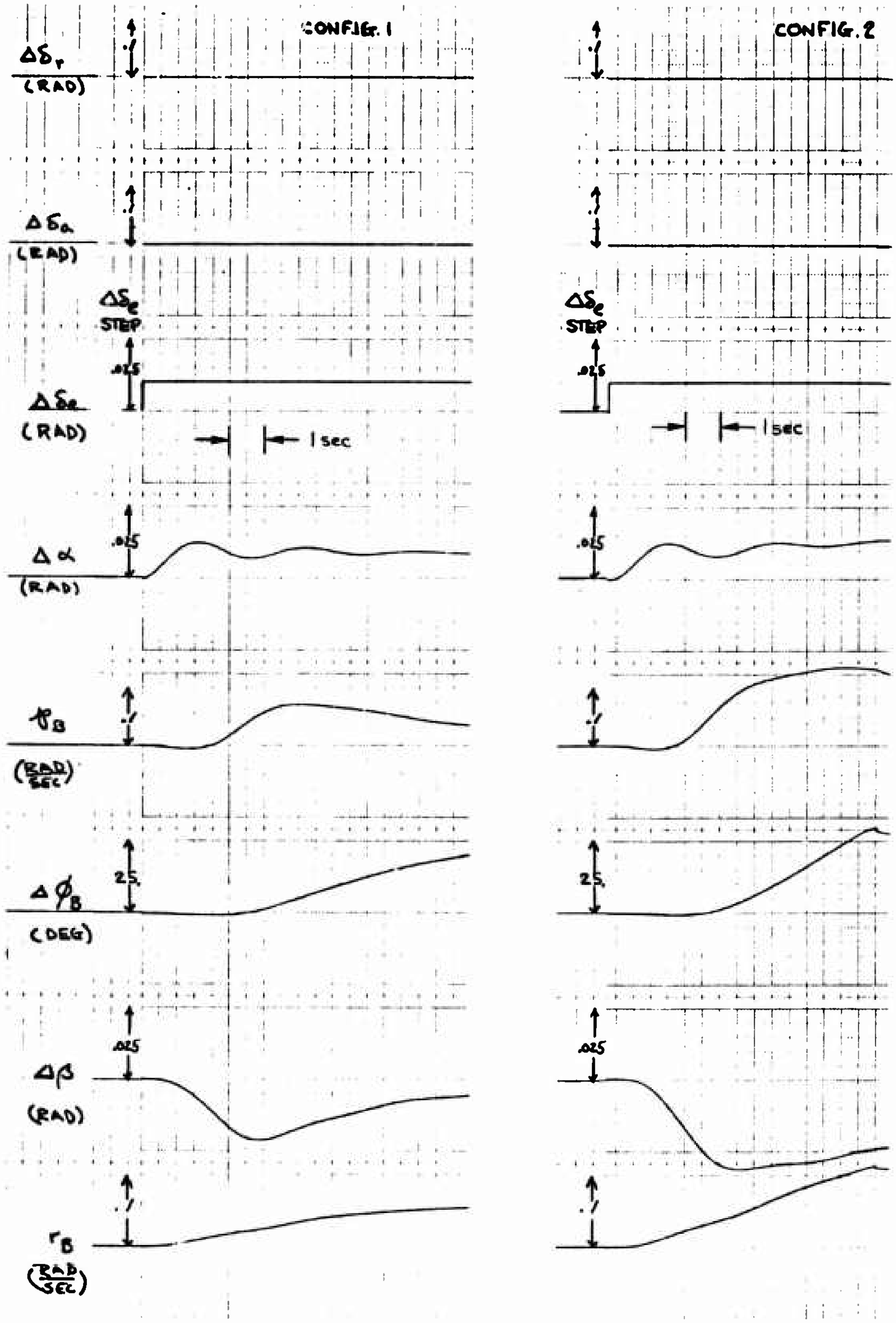

Figure 28. Step δ_e Input, Configurations 1 and 2 Lateral Responses

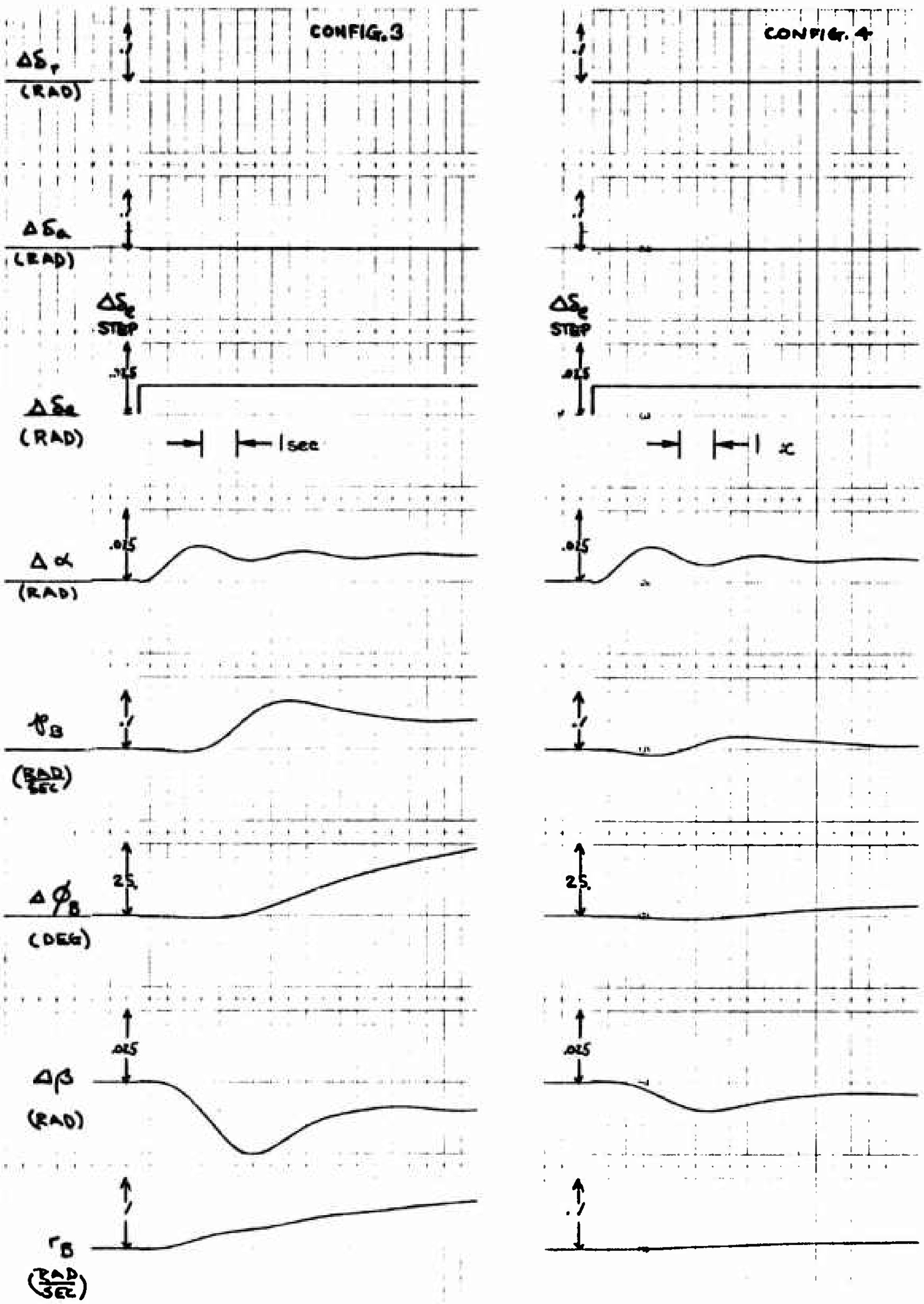

Figure 29. Step δ_e Input, Configurations 3 and 4 Lateral Responses

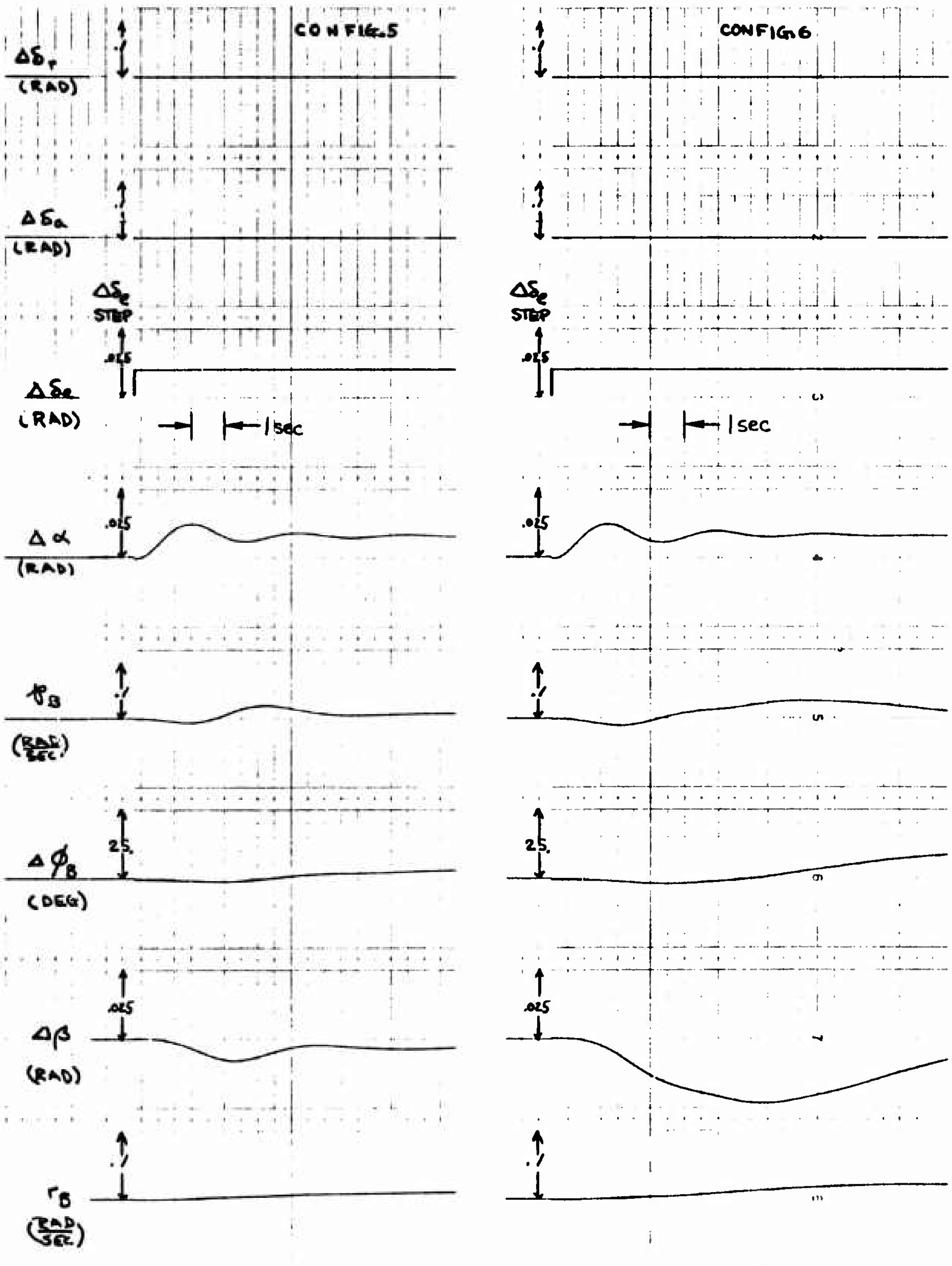

Figure 30. Step δ_e Input, Configurations 5 and 6 Lateral Responses

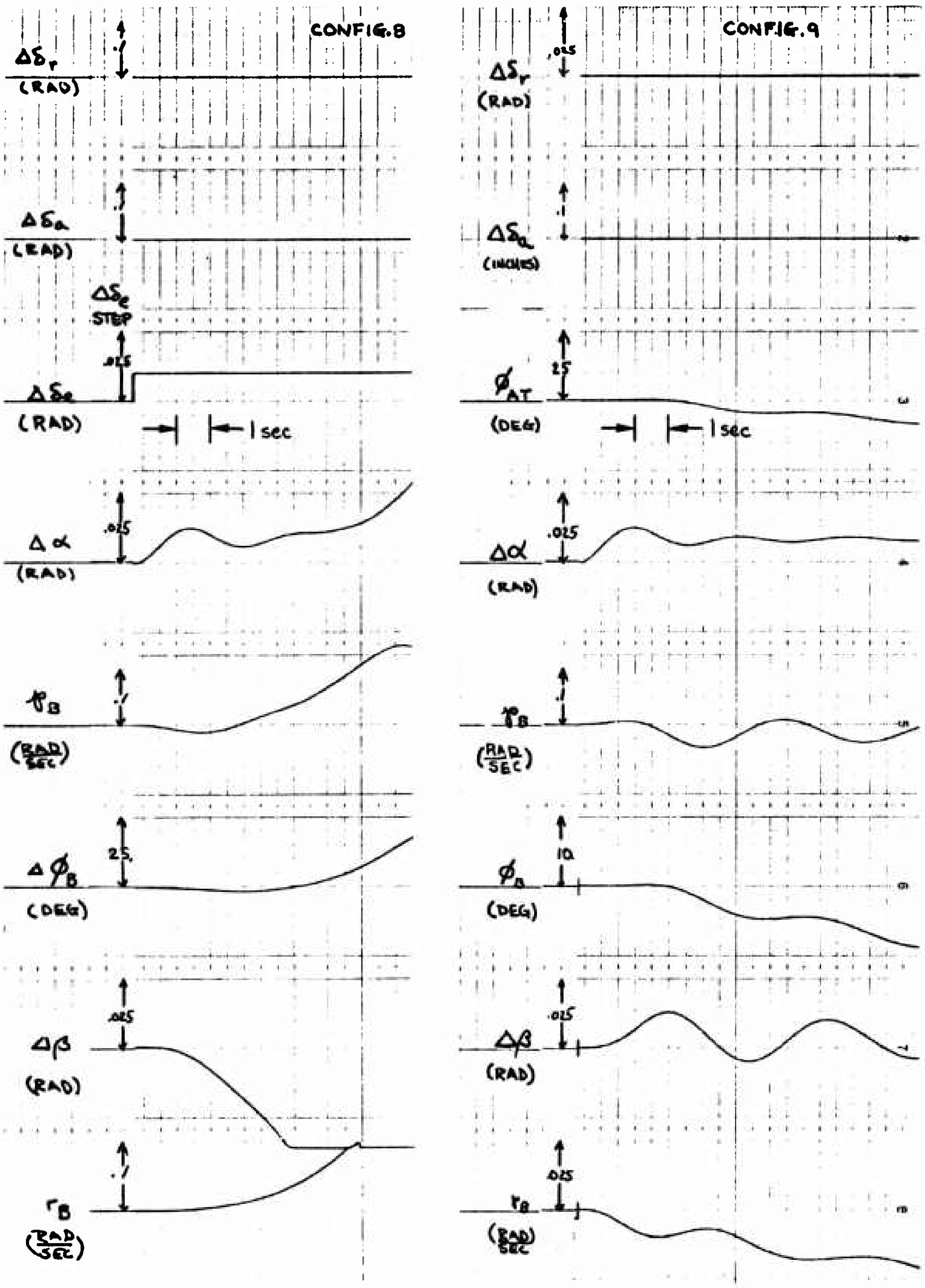

Figure 31. Step δ_e Input, Configurations 8 and 9 Lateral Responses

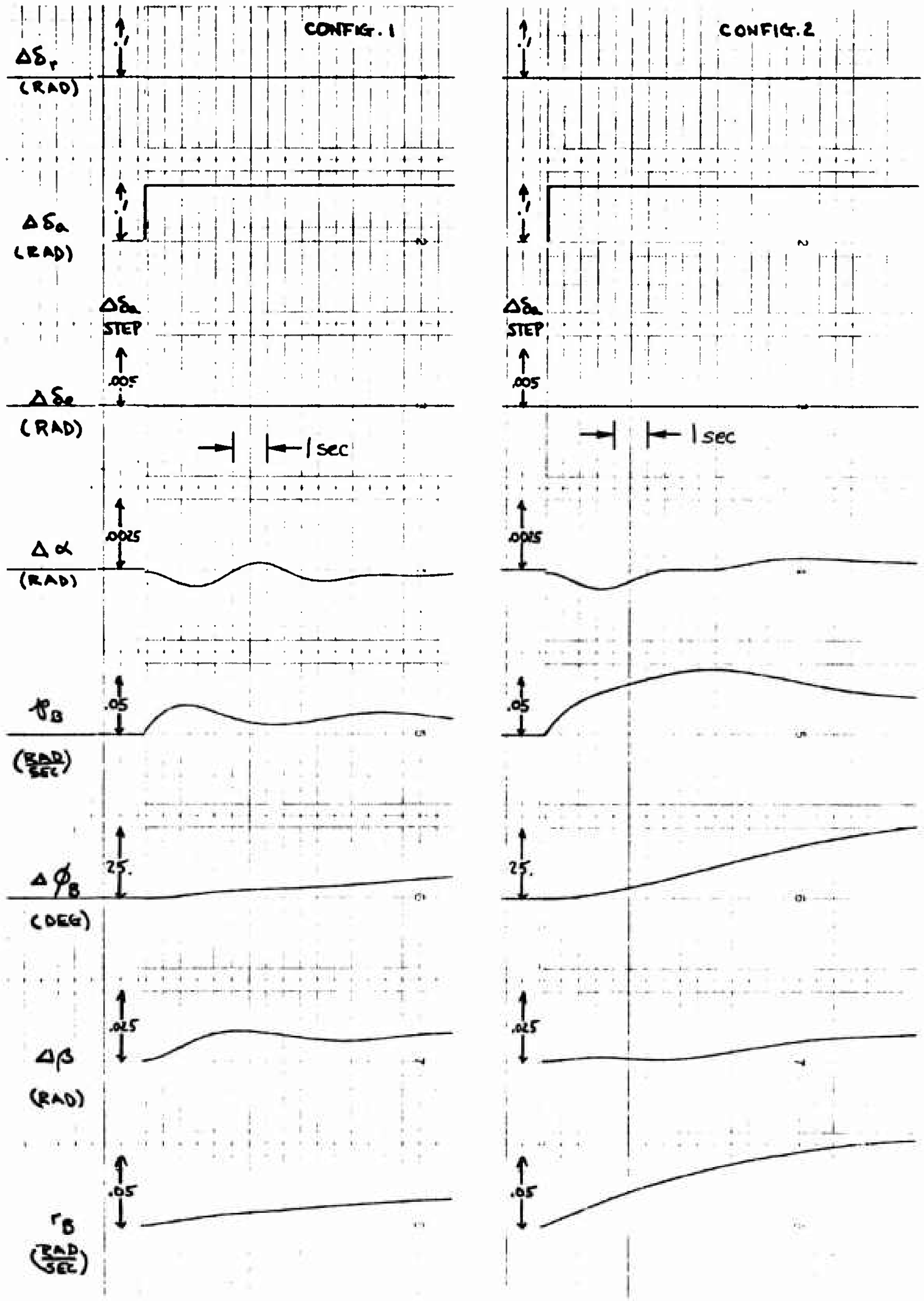

Figure 32. Step δ_a Input, Configurations 1 and 2 Lateral Responses

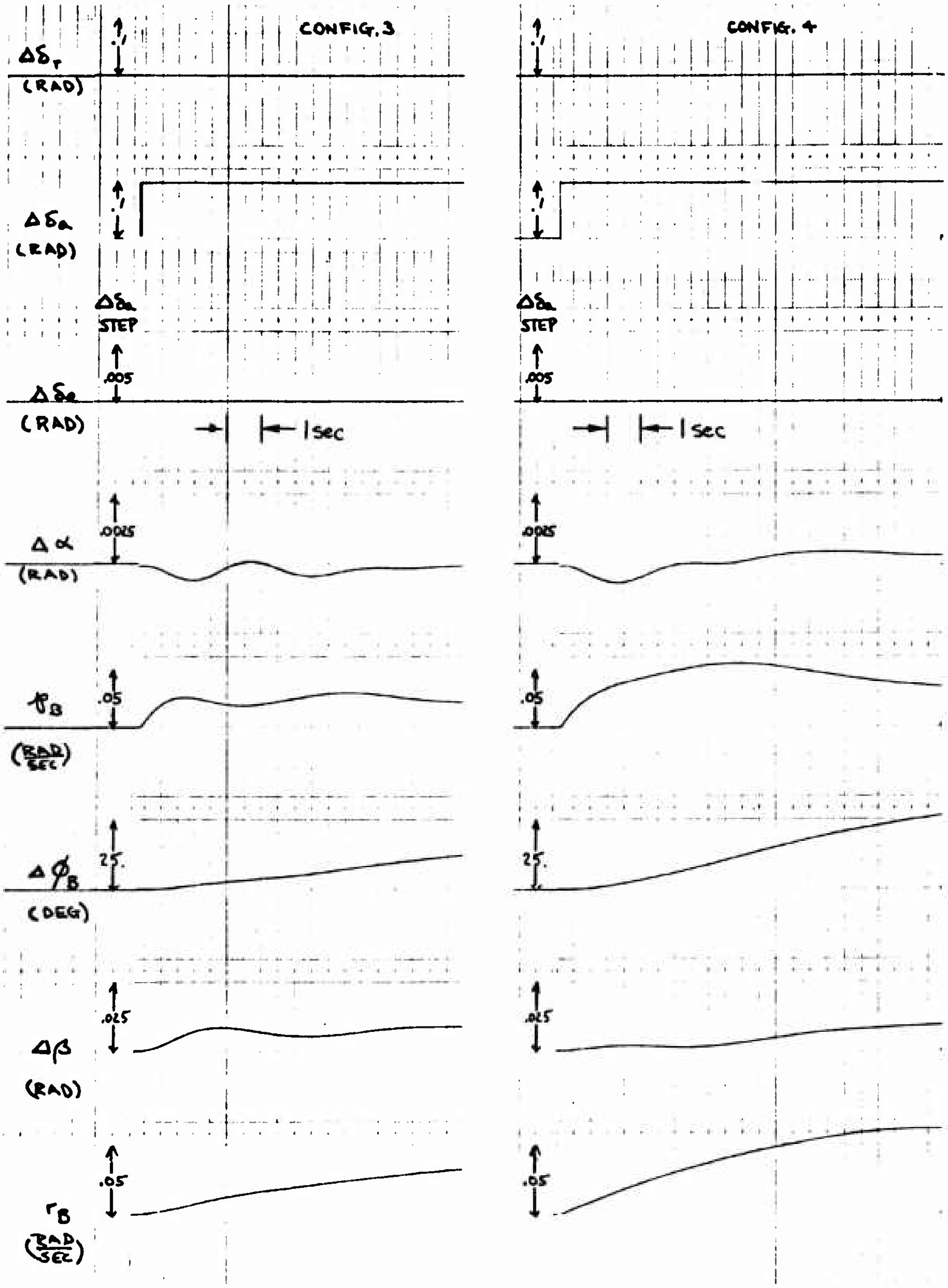

Figure 33. Step δ_a Input, Configurations 3 and 4 Lateral Responses

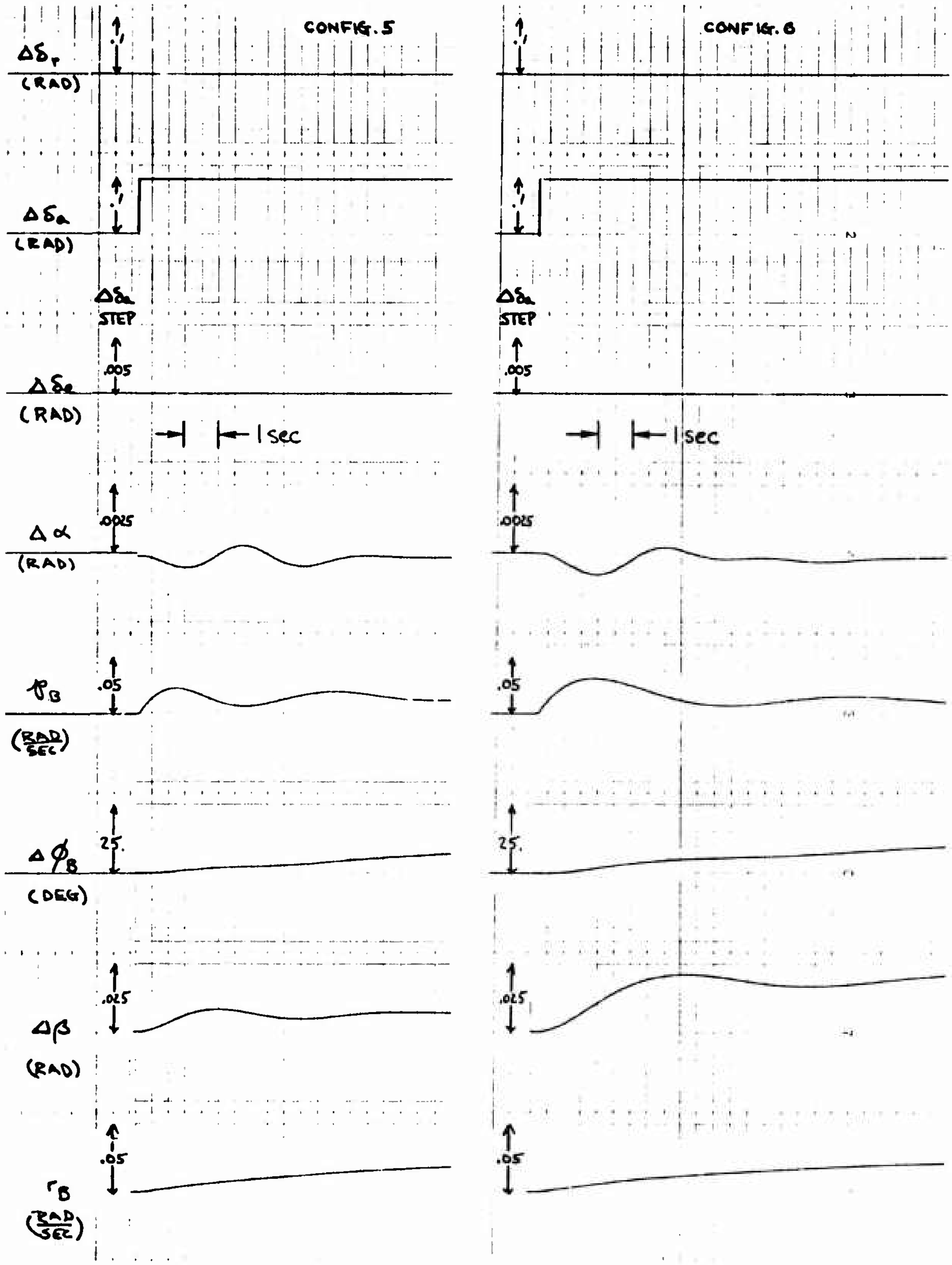

Figure 34. Step δ_a Input, Configurations 5 and 6 Lateral Responses

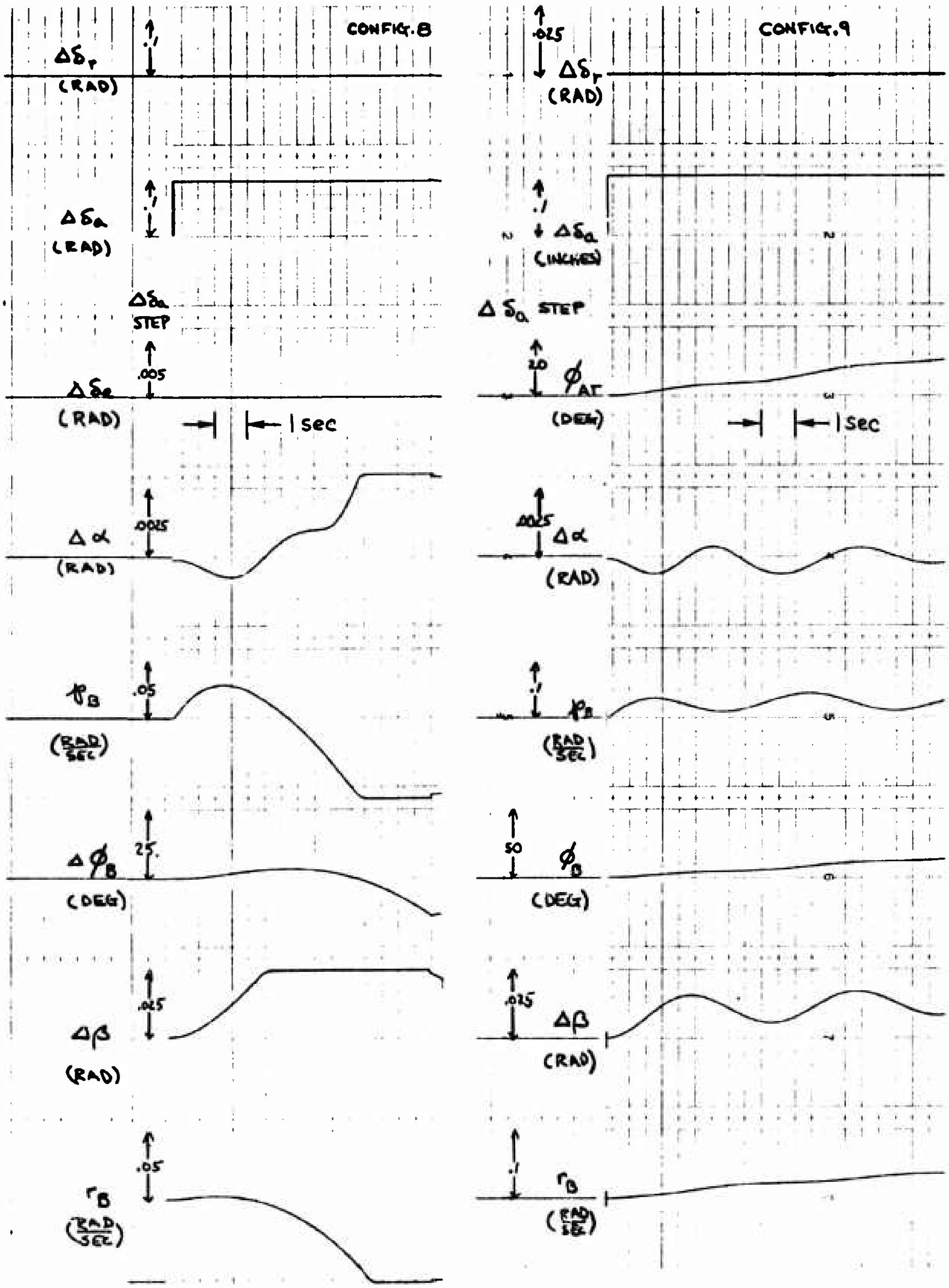

Figure 35. Step δ_a Input, Configurations 8 and 9 Lateral Responses

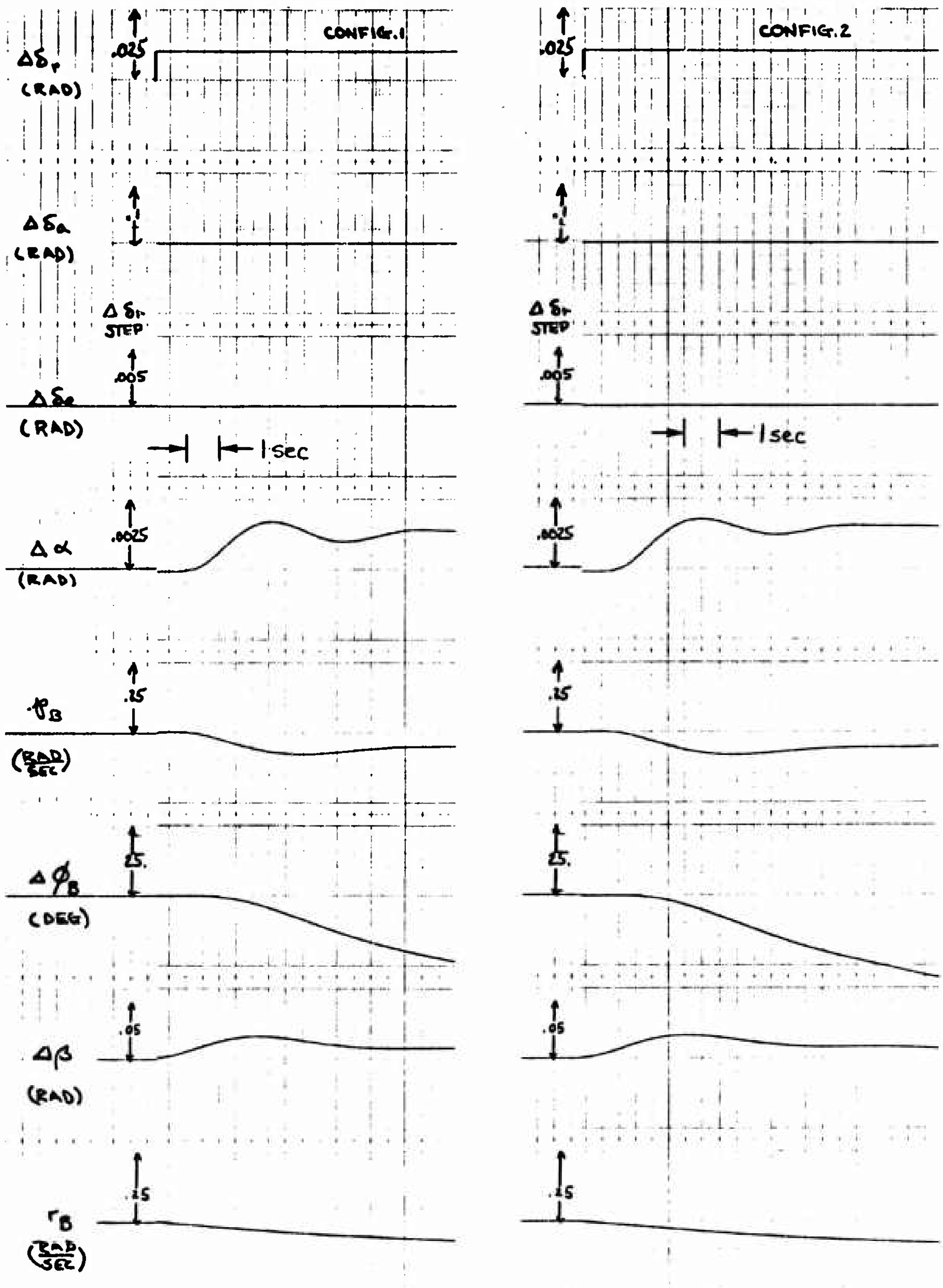

Figure 36. Step δ_r Input, Configurations 1 and 2 Lateral Responses

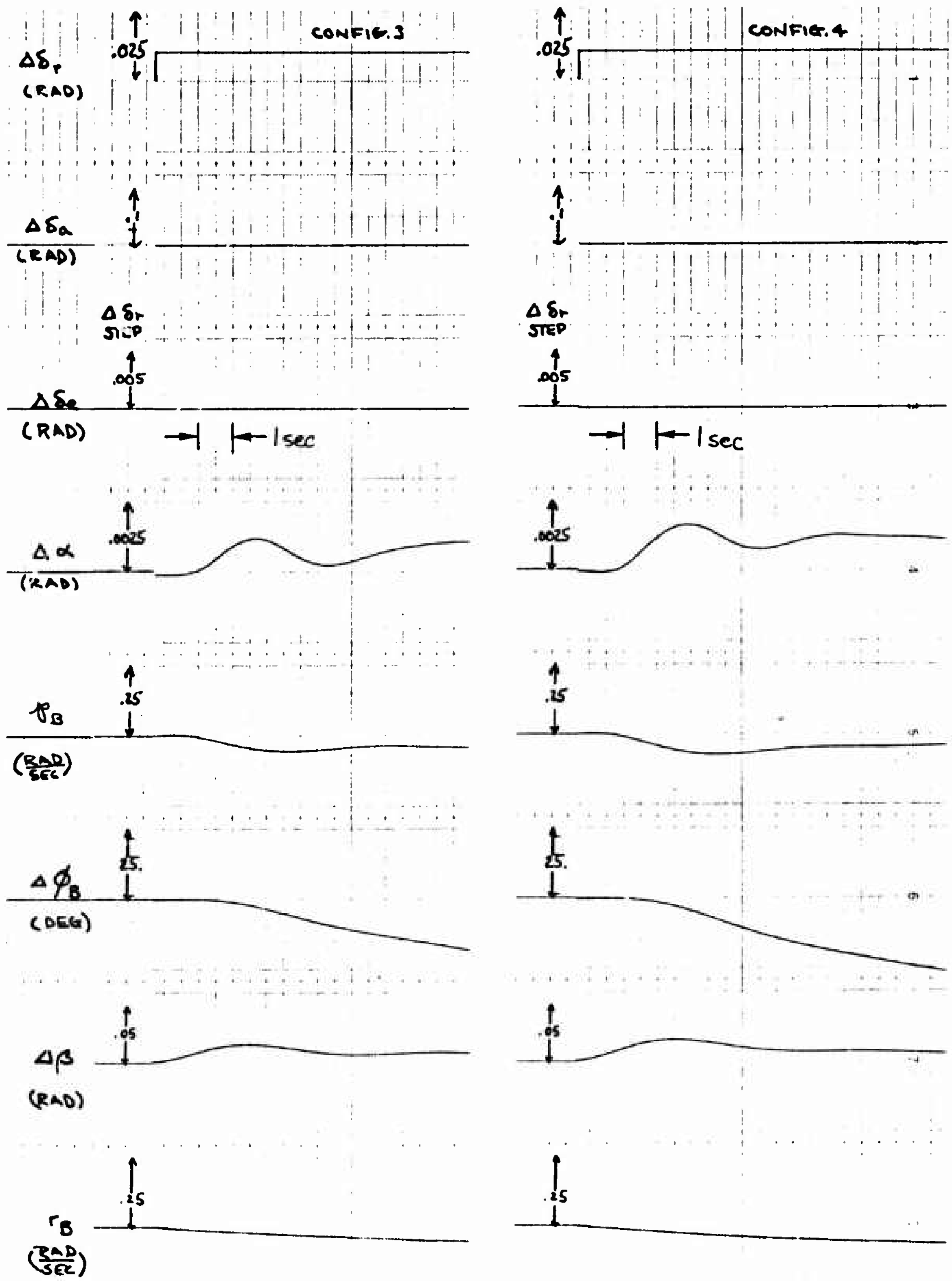

Figure 37. Step δ_r Input, Configurations 3 and 4 Lateral Responses

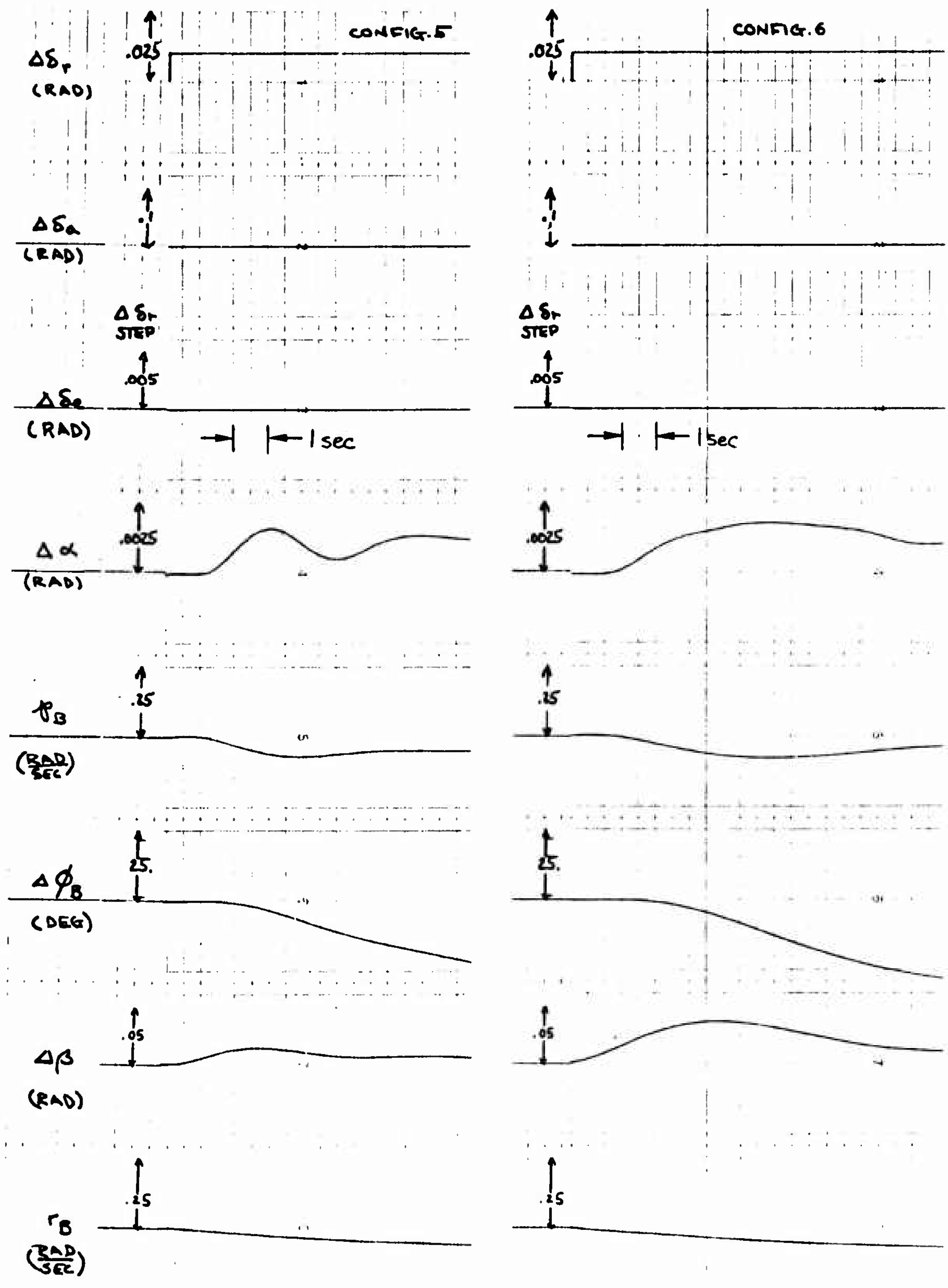

Figure 38. Step δ_r Input, Configurations 5 and 6 Lateral Responses

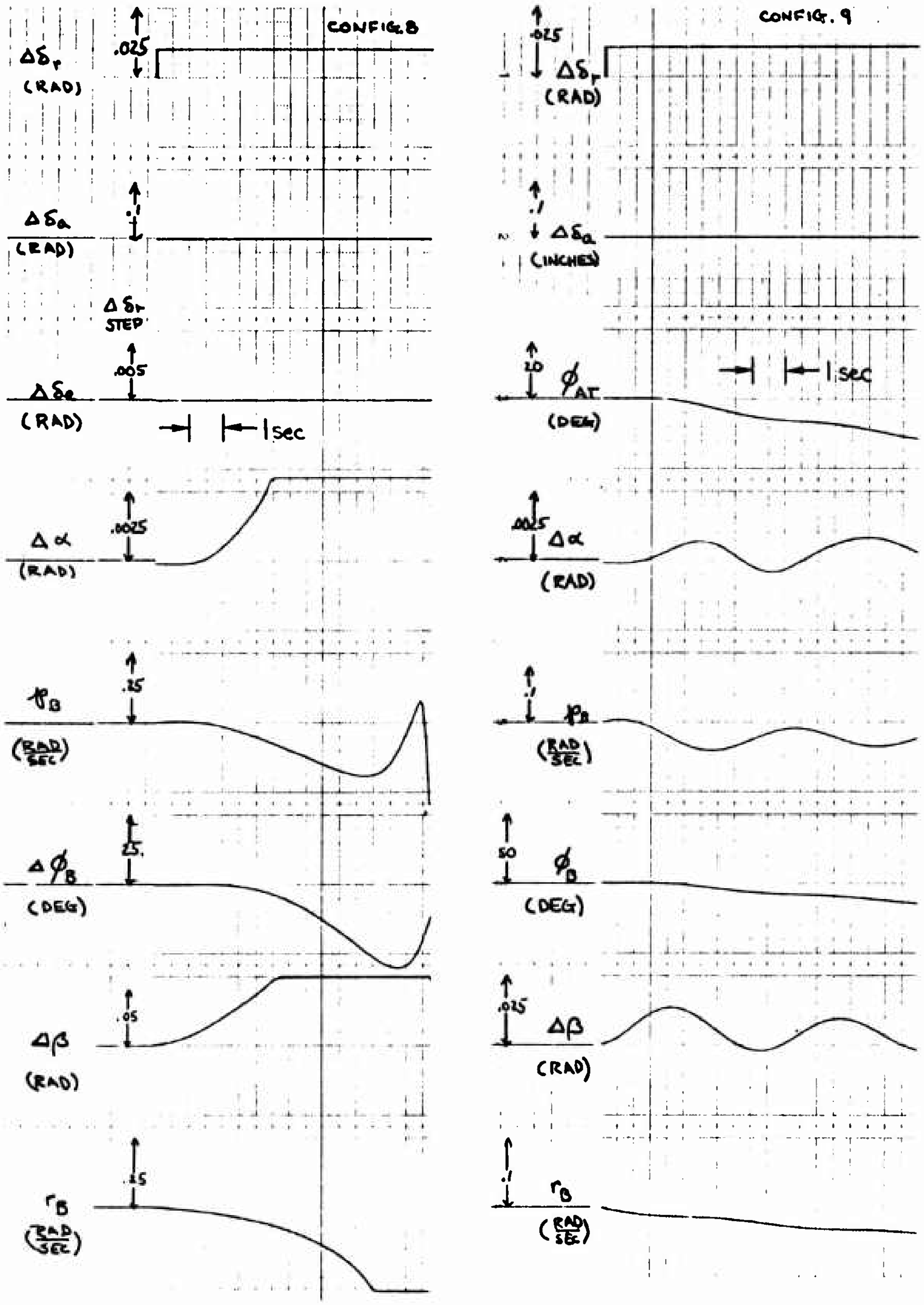

Figure 39. Step δ_r Input, Configurations 7 and 8 Lateral Responses

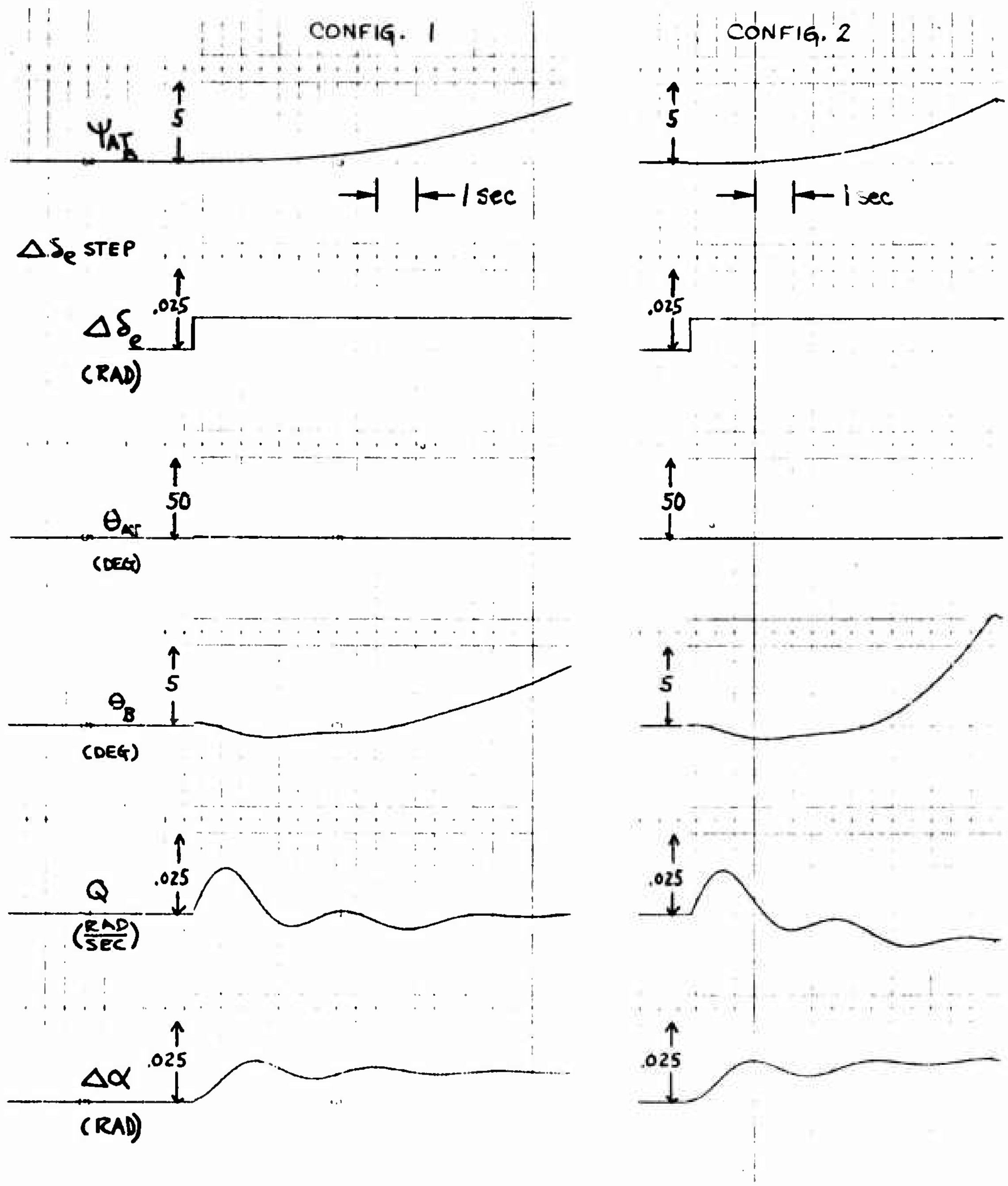

Figure 40. Step δ_e Input, Configurations 1 and 2 Longitudinal Responses

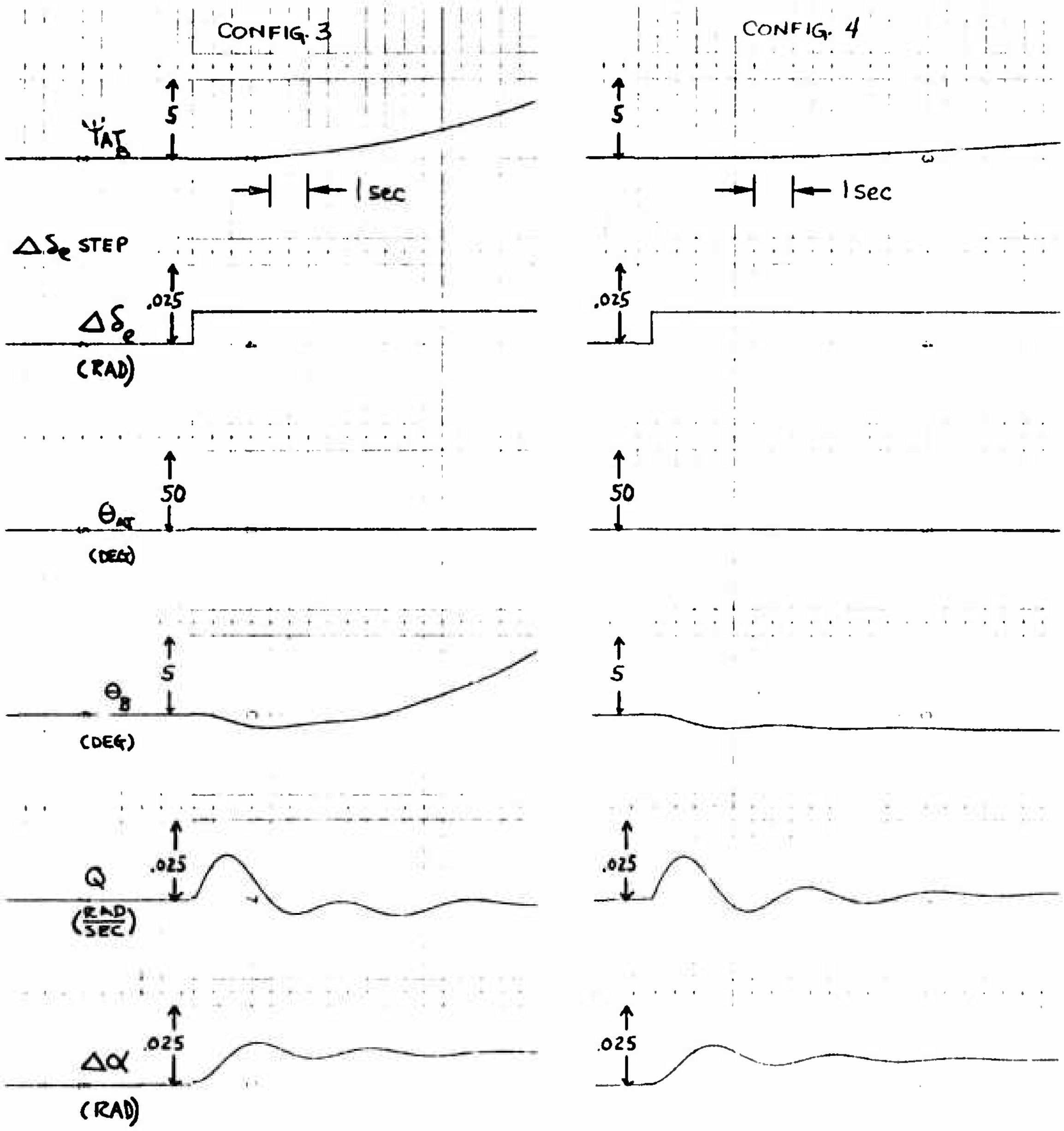

Figure 41. Step δ_e Input, Configurations 3 and 4 Longitudinal Responses

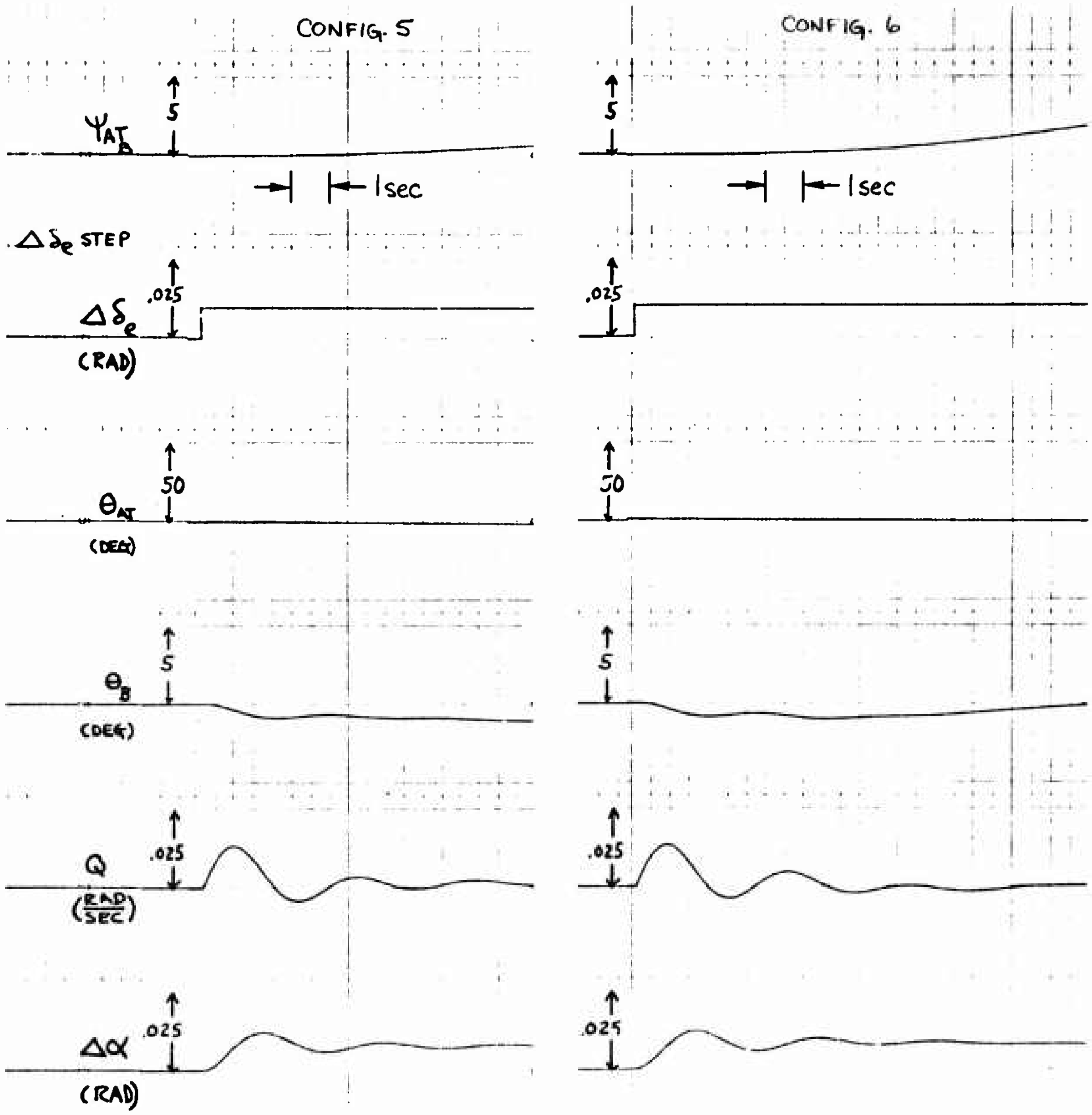

Figure 42. Step δ_e Input, Configurations 5 and 6 Longitudinal Responses

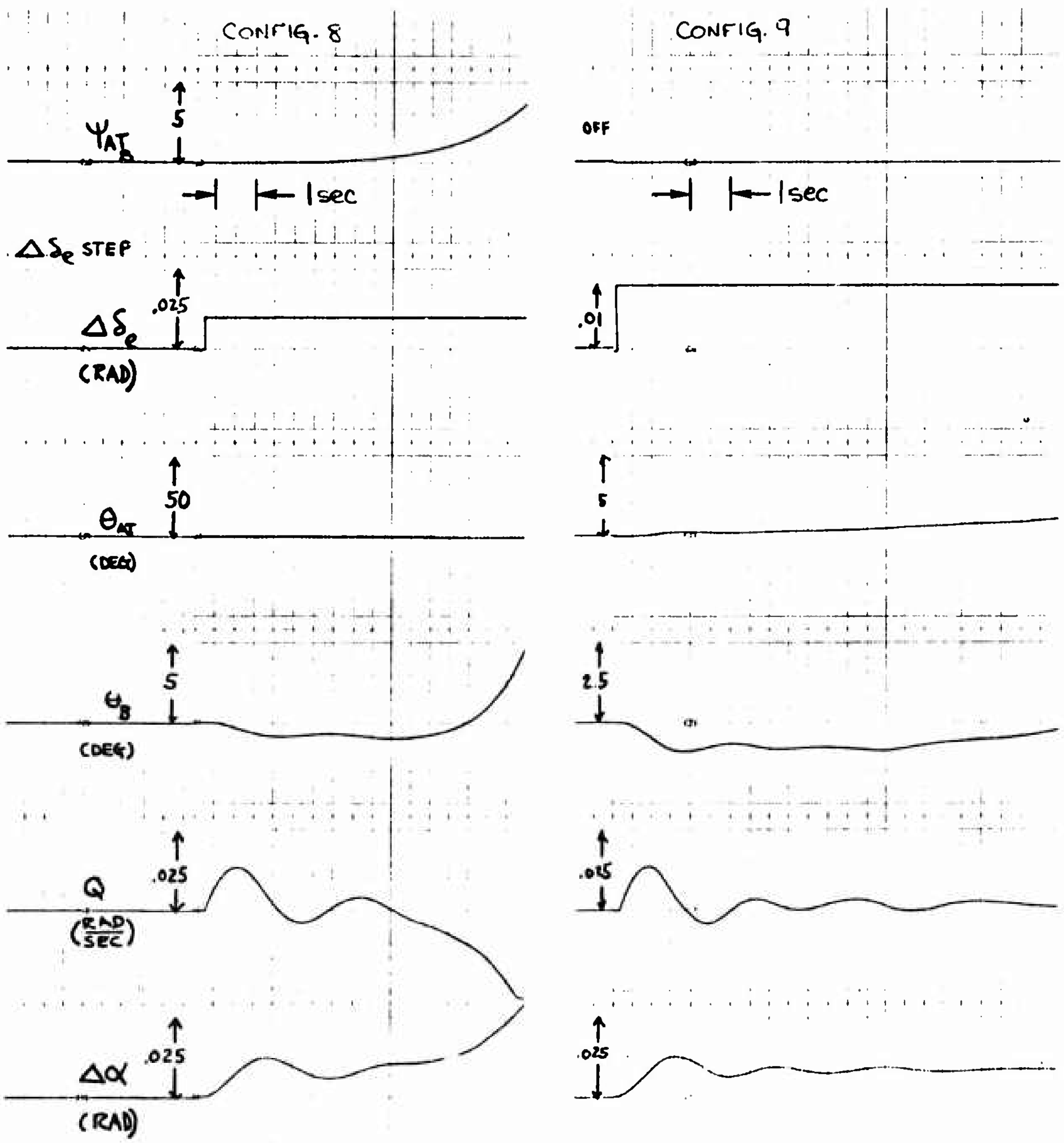

Figure 43. Step δ_e Input, Configurations 8 and 9 Longitudinal Responses

APPENDIX VI

PILOT COMMENTARY

During the piloted simulation, pilot commentrary was recorded continuously. This commentary included a description of the departure warning and its adequacy, control technique employed, recoverability of the aircraft, and the Cooper-Harper rating of the recovery task. The edited pilot commentary is presented in this appendix.

The basic task was to track a target which led the pilot into a sta and/or departure. The initial condition placed the aircraft wings-level in-trail to the target at $\alpha_o = 18.8$ deg and $\beta_o = 0$ deg. A ramp target flight path input of 1 deg/sec was commanded to obtain a consistent rate of stall approach. The pilot then followed the target aircraft flight path until departure motion was detected and/or he felt he could no longer follow the target aircraft and still achieve a successful recovery. The task thus represents a straight-ahead, paced, stall approach.

The departure cue was onset of uncommanded nose yaw with respect to the target aircraft or the realization by the pilot that the controls were ineffectual in returning his aircraft to the desired flight path. Two control strategies were employed following detection of departure. The first was to apply sustained resistive control, that is, attempt to maintain existing pitch attitude at departure detection and then to apply lateral-directional controls as necessary to resist the departure. The second was to relax longitudinal control to the zero-force stick trim position or to apply forward stick force. Five separate recovery techniques were investigated with this relaxed longitudinal stick control:

A. Aileron and rudder neutral

B. Aileron only to regain control

C. Rudder only to regain control

D. Aileron and rudder to regain control

E. Same as "D" except $\mathcal{L}_{\delta_r}$ reduced by a factor of four

Nine aircraft dynamic configurations were employed in the simulation. Configuration 1 represented the nominal A-7 dynamics. Key stability derivatives were changed to selectively control the initial condition values of the open- and closed-loop handling quality parameters $1/T_{\theta_3}$, ω_{SR}, ω_φ, ω_φ/ω_d, $N_{\beta_{dyn}}$, and ζ_d, which then varied routinely as a function of α and/or β as the aircraft approached stall. Representative values of the parameters (and derivatives) at α_o = 18.8 deg and β_o = 3 deg for all nine configurations are summarized in Table 9.

Two pilots participated in the simulation, Majors M. V. Love and J. P. Schoeppner, Jr. Major Love was given the various configurations in the sequence 1, 4, 2, 3, 6, 7, 8, 5, and 9. Major Schoeppner was given the sequence 5, 8, 7, 6, 3, 2, 4, 1, and 9. The edited commentary follows.

TABLE 9

MATRIX OF HANDLING PARAMETER VALUES AT α_o = 18.8 deg, β_o = 3 deg

CONFIG-URATION	PARAMETER										STABILITY DERIVATIVES (BODY AXIS)						
	$1/T_{\theta 3}$	ω_{SR} $(1/T_s)$	ζ_{SR} $(1/T_R)$	ω_d	ζ_d	ω_φ $(1/T_{\theta 1})$	ζ_φ $(1/T_{\theta 2})$	ω_φ/ω_d	$N_{\beta dyn}$	$N_p' - \frac{g}{U_o}$	L_α	L_β	N_α	N_β	$N_{\delta a}$	N_p	L_p
1	−.105	.238	.974	1.103	.2965	.572	.249	.518	1.28	.17	1.55	−4.0	−.712	0	.031	.02	−.8
2	−.259	.244	.957	.997	.302	.997	.184	1.0	1.28				−1.6	0	.1		
3	−.216	(.064)	(.461)	1.14	.238	.808	.176	.71	1.58				−1.6	.3	.031		
4	.015	.235	.982	1.05	.294	.992	.186	.944	1.28			−4.0	−.3	0	.1		
5	.015	.231	.978	1.25	.25	.668	.213	.534	1.77			−5.55		0	.031		
6	.015	(.222)	(.309)	.6245	.44	.392	.363	.628	.56		1.55	−1.75		0			
7	.015	(.222)	(.309)	.628	.44	.392	.363	.628	.56		.75	−1.75		0			
8	−.033	.304	−.583	.818	.878	(.781)	(−.496)	—	.0	.17	1.55	−1.75	−.3	−.5		.02	−.8
9	−.071	(.03)	(.53)	1.29	.034	.87	.14	.675	1.68	−.064	1.55	−4.0	−.712	+.4	.031	−.06	−.4

JS — CONFIGURATION 1

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta dyn}$	$N_p-(g/U_o)$
i.c.	−0.105	0.974	0.238	—	—	0.518	1.28	0.17

RUN 1A

A left nose slice at 21.3 deg. I'd say warning is adequate but it's not as slow as some of the previous nose slice rates. Releasing back stick results in a left roll, broken angle of attack, sideslip varying between plus and minus 1, and docile recovery. To avoid high rolloff, however, it requires some pilot compensation. Give that a Cooper-Harper of 4; releasing back elevator is satisfactory to prevent departure.

RUN 1B

Aileron in the direction of the departure and releasing stick back to neutral position gives adequate performance. It would require considerable pilot compensation probably to overcome the roll. So I'd say about a 5. Aileron opposite to the direction of the departure can initially delay the departure; however, if aileron is maintained opposite the departure, the yaw rate will almost stop and then accelerate. I get a roll in the opposite direction but the nose will continue to accelerate in the original direction of departure. That will have to be a 10. I can slow it down but I can't control it.

RUN 1C

Rudder opposite to the slice with releasing back pressure would have to be a 10 too. Once I build up that sideslip it really requires compensation. Well, I can control it but intense pilot compensation is required. I'd have to give that a 9.

RUN 1D

I'm going to have to give it a 9 because it takes intense compensation to try to avoid departure initially, and then I get the roll reversal and it's difficult to tell whether it's departing. That was a phasing problem. Probably be better off leaving everything alone like we proved with the elevator only. If I catch it just right, aileron with and rudder against, release the back stick, it isn't too bad. Again, it's going to take a lot of compensation.

RUN 1E

I can delay departure by stopping the nose slice in one direction and, having it revert in the opposite direction, stop it again. However, I don't really notice too much difference. Don't appear to get quite the roll oscillations that I got before with the C configuration. I don't have as high φ to β ratio as I had before, or induce a high φ to β ratio, let me say that. That's not bad; I'll have to give that a 4.

JS — CONFIGURATION 2

	$1/T_{\theta_2}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	−0.259	0.957	0.244	—	—	1.0	1.28	0.17

RUN 2A

We're getting nose slice at about 21.3, nose slicing off to the left. The indication is satisfactory; it is a very, very docile nose slice initially. A little roll accompanying the nose slice; a very, very little left roll along with the left nose slice; and the rate at which it slices is very slow. OK, I released the aft stick at 21.7 deg and departure occurred. I released it that time at about 20.4 with satisfactory recovery. Therefore, if back stick is released slightly into the stall warning at initial indication of nose slice, recovery is very satisfactory with minimal pilot compensation. There is minimal pilot compensation as far as flight control is concerned. However, the ability to recognize exactly how far into the stall you can go prior to releasing aft stick could present somewhat of a problem. Therefore, call it a Cooper-Harper rating of 4. We get the desired performance but there's moderate pilot compensation in interpreting what is being observed.

RUN 2B

Apparently, we can induce a rolling situation while maintaining the aft stick, which within the limits of the simulation appears to be a roll rather than a departure. How violent the maneuver would be is difficult to say. Since the task is to avoid departure while maintaining aft stick, it appears that we did avoid the departure within the limits of the simulation. It did require some extensive pilot compensation because we did have to apply the full aileron. Therefore, I will give it a pilot rating of 6. There doesn't appear to be much difference in whether you release the aft stick or whether you maintain the back stick. You appear to get the same results if you use the full aileron in the direction of the departure. It appears to induce a spiral rather than departure. I can't positively say that's occurring. Therefore, I'm going to make the determination that we are avoiding a departure; however, we are inducing what appears to me to be a high rate of roll, and quite a bit of pilot compensation required, and I'd say it's very objectionable. However, it is better than a departure, and whether you release the aft stick or not doesn't seem to make much difference. Therefore, releasing aft stick or maintaining aft stick would both be a rating of 6.

RUN 2C

It appears that the rudder actually aggravates the situation. If I release the rudder at first indication of stall, I can control the departure through about 6 oscillations. However, I'm faced with a phasing problem of getting out of phase. If I catch it just right and put in full opposite rudder and then neutralize the rudder at the appropriate time, and release the aft stick at the appropriate angle of attack, I can avoid the departure. But it's a phasing problem, an interpretation problem of what the maximum angle of attack is when you can achieve that, and its major deficiency — it requires intense pilot compensation to maintain control. So I'd have to give it a Cooper-Harper of 9.

RUN 2D

It looks like the best results can be obtained by using both rudder and aileron opposite to the direction of initial departure. You can reverse the direction. Again, it becomes a phasing problem. I just can't determine which combination to use and when to use it to be able to avoid departure. Releasing the aft stick helps the situation but it can't positively avoid the departure in each case. I feel like the rudders are aggravating more than the ailerons have in the past. I'd have to give the aileron and rudder together a 10 rating, just because I can't seem to get it all together. I don't know whether I'm coupling them together or I can't coordinate them to the best advantage.

RUN 2E

Using the rudder it appears I reverse the direction of the initial nose slice and then, relaxing the back stick and breaking the angle of attack. I can control the roll rate by using rudder. However, phasing does appear to be a problem in that you have to apply the rudder at the appropriate time in order to avoid building up excessive sideslips. It does require excessive compensation. I can control it if I apply considerable pilot compensation. Let's call it a Cooper-Harper of 8; it predominantly results from releasing the aft stick. And it's a 10 if the aft stick is maintained.

JS — CONFIGURATION 3

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_ϕ/ω_d	$N_{\beta dyn}$	$N_p-(g/U_o)$
i.c.	-0.216	—	—	0.461	0.064	0.71	1.58	0.17

RUN 3A

Initial nose slice to the right at about 21.3 deg. At initial indication of nose slice, stick is released, recovery is rather mild, and moderate pilot compensation is required. In fact, I'd call it minimal pilot compensation for desired performance, which would be a Cooper-Harper of 3. The indication of departure is adequate well into the stall warning. The rate of the nose slice is slow enough that it can be observed and aft stick released to avoid departure. It's very docile.

RUN 3B

Nose initially sliced to the right. Aileron against the direction of the nose slice was applied. Departure in the initial direction was stopped. Motion reversed, accompanied by a rather fast roll rate which resulted in departure. It'll be a Cooper-Harper rating of 10. It appears in this configuration aileron with or against the direction of departure aggravates the situation to where the aircraft will depart more readily. We're limited by the simulation to the extent that we can't evaluate what happens after the stick is placed full forward excepting to note the angle of attack is not showing a departed condition. Therefore, we have to give it a Cooper-Harper rating of 8. And all other use of the aileron would be a Cooper-Harper rating of 10.

RUN 3C

It appears that if the rudder is held in, departure will occur. Initial input of rudder opposite to the direction of departure will slow down departure and cause a reversal in the opposite direction. Releasing aft stick and neutralizing the rudder will then avoid the departure. So, a combination of releasing aft stick and neutralizing the rudder at the appropriate time will avoid the departure, so I receive adequate performance. However, I have to compensate extensively — knowing when to release the aft stick, when to neutralize the rudder; and it would be a Cooper-Harper rating of 6.

RUN 3D

I can significantly delay the initial direction of the nose slice, in fact, causing it to stop. However, slight roll rate is built up and then the nose continues to slice in the original direction accompanied by a roll and departure follows. That's full opposite rudder and aileron with. Again, it's a phasing problem. There doesn't appear to be any way, using both ailerons and rudder either with or against the direction of the departure, to avoid the departure other than delaying it. It appears that the ailerons are perturbing the situation. Any aileron input at all makes the situation uncontrollable, and releasing aft stick will not avoid the departure. I'd have to give that a Cooper-Harper rating of 10. I just can't convince myself that using ailerons is not more severe than not using ailerons. I feel that I've got much more control over the problem by using the rudder and releasing aft stick than I do by putting any aileron into or against the direction of the departure.

RUN 3E

I can release the stick and effect a recovery. But I can't reapply any back pressure at all because as soon as I do I get back into the stall condition, which you would expect in fact. Normally, if you recover from a spin too soon, put back pressure back in, the thing will spin in the opposite direction. That's exactly what's happening right here. By using the rudder along with releasing aft stick we can go a little deeper into the stall, go a little farther into the nose slice, release the aft stick, and then bring the nose back to the neutral position by using the rudder. It gives a little more capability to perform the task of tracking the target since we can stay in the stall condition just a short time longer than if we just use the elevator alone. So, I would have to give it a Cooper-Harper rating of 3 because it is satisfactory without improvement. I can even stay in the stall condition a little bit longer because I now have the rudder available to neutralize the yaw rate. However, there's some difficulty in phasing, and you build up some rapid yaw rate. You can tell by the angle of sideslip changing. So, phasing can be some problem. I feel that with the yaw excursions that we're getting and the fact that we can control them through that range with the rudder makes it a rather satisfactory flight condition. And then I can have the nose slicing back and forth and still not experience a departure by driving the angle of attack way up. I'd say it was a 3.

JS — CONFIGURATION 4

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	0.982	0.235	—	—	0.944	1.28	0.17

RUN 4A

I'm getting the shaker and the nose slice at about the same. The shaker is set at 21.3 deg and I'm getting a nose slice at 21.4. It's a very docile nose slice initially, off to the left in this case, warning is quite adequate, rate rather slow. Extremely easy to control by releasing aft stick even after you're in the 21.4, 21.5 deg α range about 7 sec. So initiating recovery at initial stall warning, nose slice rather docile, rather docile recovery, little or no compensation required with the exception of releasing the aft stick. And I'd have to give it a 3.

RUN 4B

It appears that I can drive it into a spiral as opposed to going into a departure, and that's aileron with, maintaining the aft stick. However, it does take considerable compensation. Really can't define what's happening. I'd have to call it about an 8. OK, this will be Configuration 4 Bravo again, releasing aft stick when the aileron's applied. Again, it's difficult to tell — it's basically the same. That looks about the same as what I had with maintaining the aft stick. I'd have to give that the same pilot rating. It looks though that aileron in the opposite direction of the departure is more satisfactory in this particular configuration.

RUN 4C

I can ride into the stall pretty nicely in this one, release the aft stick, come in with the rudder. I'm getting quite a bit of roll in this one, not really too much yaw rate, real high φ to β ratio. If I don't ride into the stall too long and use the rudders to control the direction of the initial nose slice, I can compensate for it but it does take rather intense effort. I'm not getting high rolloffs — this is with the release of the back stick. I'd have to give it a 6.

RUN 4D

I can reverse the directions of the nose slice but I can't predict which controls to use. Sometimes it appears to be better to go aileron with, sometimes aileron against. I can ride up in the higher angle of attack region, the stall region, for a bit longer and track the target a little bit better. But I have a phasing problem, and I start applying the controls — be it aileron or rudder — and I get to the point where I've started building up these roll-yaw oscillations to a point where I cannot get the proper controls in at the proper time in order to avoid the departure. It really takes a lot of compensation because the roll rates are building up so much. I'd have to give it an 8.

RUN 4E

I've got the ability to ride up in the higher angle-of-attack regime for a longer period of time. I can control the initial nose slice with the rudder, but once the nose goes back to neutral I have to release the back stick. I get quite a bit of roll rate built up which I can't control. It seems to me a little bit better than I could control with Configuration 4C. It seems like I've got just a little bit better control over roll with rudder.

JS — CONFIGURATION 5

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_ϕ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	0.978	0.231	—	—	0.534	1.77	0.17

RUN 5A

Configuration 5 elevator alone. Left nose slice about 22-1/2 accompanied by a roll, back stick released, departure's averted. Departure can be averted by releasing back stick. Departure warning is satisfactory. You hit the rudder shaker angle of attack considerably before the nose begins to slice. Once the nose does begin to slice, the rate of yaw is slow enough that the departure can be observed in time to release back stick and avoid the departure. That would be a rating of 4 in that desired performance, which is avoiding departure, required moderate pilot compensation to the extent of releasing back stick.

RUN 5B

Departure appears to slow somewhat with application of aileron opposite to the direction of departure. By slowing down the rate of departure, back stick can then be released and forward stick applied which will avoid the departure. However, considerable pilot compensation is required and that would be a Cooper-Harper rating of 6. Adequate performance requires extensive pilot compensation.

RUN 5C

By controlling the initial departure with rudder alone, I can delay the departure, and then by releasing back stick it appears that I can avoid departure. I don't know whether I'm hitting the limits of the simulation or its actually departing on about the third roll. I would guess it's the limit of the simulation, and I would say that by using rudder to delay the onset of departure, and then by releasing aft stick the departure can be avoided, and it's adequate performance but it requires extensive pilot compensation and would be a rating of 6.

RUN 5D

Ailerons appear to aggravate the departure in any case. We're basically delaying the departure by use of rudder alone. In this case I used rudder against the direction of departure and aileron with. I get the same result as with rudder alone, if I release the aft stick and delay initial departure with the rudder, I can then avoid a departure. Ailerons appear to aggravate the problem by inducing roll so the results would be the same as with rudder only.

RUN 5E

OK. I appear to have a little more rudder authority. Maintaining the aft stick at the stall warning, I can delay the departure through about 2 more oscillations in yaw and roll as opposed to the rudder alone results of Configuration 5 Charlie. If you release back stick you can control the departures so the same ratings apply.

JS — CONFIGURATION 6

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\delta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	—	—	0.309	0.222	0.628	0.56	0.17

RUN 6A

Departure first noted at about 21, nose slice about 21.4 deg. The departure warning is adequate since the rate of nose slice is rather slow. The nose slice is accompanied by right wing low with the nose slice off to the left. Recovery by releasing aft stick alone at first indication of departure. I'd say recovery is satisfactory. I get some left rolloff. It's controllable, so it would be a rating of 4. We avoid a departure, get the desired performance, and it does require a moderate pilot compensation by realizing he's in a departure and being able to release the stick at the appropriate time. However, you can go well into the rudder shaker in this case and still release the stick without the aircraft departing.

RUN 6B

Aileron opposite the direction of departure and releasing aft stick appears to be controllable to a certain extent within the limits of the simulation. However, intense pilot compensation is required, and I have to give it a rating of 9.

RUN 6C

Rudder opposite the direction of the departure and release aft stick cannot avoid the departure. A rating of 10. Opposite rudder, full forward stick, and if I didn't tear the wings off the airplane, I probably avoided a departure. However, that requires considerable pilot compensation and the motion after the full forward stick is difficult to define because of the limitation of the simulation. Therefore, I'd have to call that a Cooper-Harper rating of 8.

RUN 6D

Ailerons just seem to aggravate it. Even releasing aft stick does not help to avoid the departure. OK, using the rudder and the aileron, holding the back stick or releasing aft stick to neutral position, would be a 10. Rudder and aileron with full forward stick would be an 8.

RUN 6E

Once it makes its mind up to go do its thing, there's not much I can do about it holding aft stick and using rudder alone. Rating of 10. Releasing aft stick with opposite rudder still cannot avoid the departure. Rating of 10. I don't notice any considerable difference for this configuration opposed to the Charlie configuration. Full forward stick again appears to avoid the departure; however, it's difficult to evaluate because of the limits of the simulation. I'd say it requires considerable pilot compensation which would be a rating of 8.

JS — CONFIGURATION 7

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_ϕ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	—	—	0.309	0.222	0.628	0.56	0.17

RUN 7A

Initial departure is a left nose slice about 21.3 with a slight right roll. Recovery can be accomplished by releasing back stick. I get a nose left with a slight right wing low; however, recovery is satisfactory and requires moderate pilot compensation to avoid the departure. Rating of 4. The initial warning of departure is satisfactory in that the nose slice at a rather slow rate which can be observed and back stick adequately released.

RUN 7B

By applying aileron the rate of departure can be slowed down momentarily; however, recovery cannot be effected using ailerons alone, resulting in pilot rating of 10.

RUN 7C

(Pilot commentary lost due to tape recorder jam)

RUN 7D

Apparently the aileron aggravates the situation more than the rudder. Use of rudder and aileron while releasing aft stick is a Cooper-Harper rating of 10. It appears that if you apply full rudder opposite and rull aileron with, the departure can be avoided. However, it's difficult to evaluate because of the limitation of the simulation. Use of ailerons and rudder accompanied by full forward stick occasionally will avoid the departure. However, since it cannot be controlled in every instance, the rating will be 10.

Run 7E

No apparent difference is noted between this configuration and Configuration 7 Charlie. Releasing aft stick and using rudder, departure is not avoided; rating of 10. Rudder opposite with full forward stick and the departure can be avoided. Requires extensive pilot compensation; rating of 8.

JS — CONFIGURATION 8

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	−0.033	−0.583	0.304	—	—	—	0	0.17

RUN 8A

Nose slice to the left at about 21 deg. Release the back stick at initial nose slice and departure cannot be prevented. The warning of departure is inadequate because the yaw rate associated with the departure is such that with about 15 deg of nose slice, releasing back stick will not prevent the departure. So, departure prevention with the release of stick alone would be a rating of 10. Full forward stick at first indication of departure appears to be satisfactory. Again, it's difficult to tell because we get a roll reversal which is not completely visible on the viewing screen, but it does require extensive pilot compensation to avoid the departure, extensive compensation being full forward on the control stick. Therefore, rating would be 6.

RUN 8B

The use of ailerons either with or against the direction of departure, accompanied by full forward stick, is not adequate to avoid the departure, resulting in a Cooper-Harper rating of 10.

RUN 8C

Let's give it one shot with the rudder alone. I think I'm going to see the same thing. This will be rudder against the direction of departure. And can't tell what it's doing. Full opposite rudder, full forward stick will not avoid the departure; therefore, rating is 10.

RUNS 8D AND 8E

No use in trying, neither aileron or rudder has any effect.

JS — CONFIGURATION 9

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_ϕ/ω_d	$N_{\beta dyn}$	$N_p - (g/U_o)$
i.c.	−0.071	—	—	0.53	0.03	0.675	1.68	−0.064

RUN 9A

About 22.2 deg, left nose slice, release the back stick, get a left rolloff. It looks like it's neutral to slightly convergent dutch roll. But I'd have to give it about a 3 rating as far as easy recovery by releasing the aft stick.

RUN 9B

OK, I get a pretty good left rolloff; however, I have not reached the angle of attack which would indicate a departure. Take some pilot compensation in order to decrease or eliminate the roll. Difficult to tell because of the limitations on the simulation. So I would say it'd be a 6. That's releasing back stick, aileron with. Let me try aileron against, and release back stick. The stick release tends to break the stall and the aileron in the direction of the original nose slice tends to slow down the rate of nose slice; however, it then begins to accelerate again and, as would be expected, it departs. I'll have to give that a 10.

RUN 9C

Well, you can stop the nose slice in the original direction; however, there's a rapid reversal accompanied with the roll in the opposite direction. And departure occurs. You can change the number of oscillations depending on how quickly you apply rudder in one direction or the other. And the direction being the direction opposite to the nose slice. I'm out of phase and all I do is aggravate it by using the rudder; probably be better just to let it go. Rather high φ to β ratio. I just release everything and it is damped, so using rudder does nothing but aggravate the situation. It's a problem trying to get in phase with it. The dutch roll is easily aggravated. It can be recovered by releasing back stick and using opposite rudder. However, it takes considerable pilot compensation to overcome the associated dutch roll which was probably excited mainly by the pilot applying the rudders. So I'd have to give it a 8.

RUN 9D

OK, rudder against, aileron with, release the aft stick, it goes into a rapid roll rate and we've got a nose pitching up and down above the horizon. It's a real phasing problem. I just have so much dutch roll that I can't pick the proper combination of ailerons and rudder. In fact, trying to use both of them is actually more aggravating than using one or the other. I'd have to give that a 10; I'm just lost to try to control it.

RUN 9E

OK, I'd give that about a 6. I can control it.

ML — CONFIGURATION 1

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_ϕ/ω_d	$N_{\beta_{dyn}}$	$N_p-(g/U_o)$
i.c.	-0.105	0.974	0.238	—	—	0.518	1.28	0.17

RUN 1A

It depended on how aggressively I tracked the target directionally with the rudder whether or not I got a good cue to start the recovery. When I tried to track the target with the rudder, by the time I decided I needed to recover and released back stick, it was too late and it departed anyway. In the case of just releasing the stick and not aggressively tracking the target directionally, it is controllable. For the task of detecting and recovering from a departure, you really have to pay attention to when the nose slice starts or it would be easy to go too long. So I would say that it takes a lot of pilot attention. It's not satisfactory without improvement. As soon as the nose slice starts you must recover, and it's not a very good cue. You just have to be kind of mechanical and say, "If the nose is starting, I have to recover." Then, to recover, you just push your stick straight forward. I feel it's a more positive recovery. I like that better, so I'd rate stick push a 5 and stick release a 6.

RUN 1B

In that last one, as soon as the target started to move to the left I said, "OK, it's going," and I put the stick forward and put the aileron in. I can delay the departure but it doesn't seem I can finally arrest the sideslip. OK, we've done about 5 or 6. And I've found that the cue for the departure is even less than I thought it was on the first occasion. I found that as soon as I'm unable to track the target I've really got to start a recovery, or I'm going to be unable to arrest the sideslip. If I start a recovery with stick frozen, as well as I can, and use aileron, it's uncontrollable. And that's a 10. If I start a recovery by relaxing back pressure as I put in aileron to try to arrest the nose slice, it's still uncontrollable. I'm able to delay the departure but I'm not able to finally arrest the sideslip and so that's a 10 too. The motion's a little different. Departure's delayed maybe one full cycle of change in bank angle from right to left, and then it finally departs. If I push the stick forward and then go after it with the aileron, I can arrest the departure and bring the sideslip back to zero. So I can recover by using forward stick and aileron. It's very difficult to do that tracking task at all without getting a departure, but I can control it in that last case. However, it requires, let's say, considerable pilot compensation. I'd give it an 8.

RUN 1C

If you relax the back stick and try to arrest the nose slice with rudder, you may or may not recover. In one case I did and in one I didn't. So I'd put that as a 9. You have to go to some cue, like the ball, and get right on it and disregard everything else. You can control it but it takes intense pilot compensation. If you go to forward stick along with the rudder then it's a much better situation. I feel that it's just as good as the aileron. So I'd give it a 5 in that case. That's stick forward of the trim and arresting sideslip with rudder at the same time.

RUN 1D

If you release back stick and use aileron and rudder to bring the sideslip to zero, you can do it but it takes a lot of effort. However, it's more natural to do it that way than to do it with just one axis or the other. And I'd rate it above the 9 I gave before I'd give it an 8. OK, if you push forward on the stick and chase it with aileron and rudder, I don't like it as well as just being able to push the stick forward, or even as well as pushing the stick forward and just using rudder. I think the reason is I get a lot faster roll response. So I'd rate pushing the stick forward and using aileron and rudder as a 6, where I had said 5 before. And the reason is it just complicates the recovery.

RUN 1E

OK, in the case with L_{δ_r} it recovers pretty nicely. There is a problem. I think there is a deficiency in this that's not quite as apparent. It's different in that if I try to track this one closely, I can do a better tracking task as I bring the nose up because I can push in rudder and the nose will go over and track the target, and the airplane doesn't roll and I don't seem to generate the slice that I do if L_{δ_r} is bigger. Therefore, it's a little harder to tell if you're going to depart. I believe if you look at the record you'll see I'm driving a little higher in angle of attack before I'm giving up. It fools me because I have a better directional control. It has an objectionable, but tolerable, deficiency in that the clue for departure comes a little late because you think you're tracking, but it's easy to recover by simply releasing the aft stick. I'd rate that a 6. And the reason it's a 6 is it doesn't require much pilot effort to effect recovery but it does require good pilot effort and concentration to tell it's time to make the recovery. Now if I use rudder during recovery I tend to overcontrol in sideslip and I don't always recover. It's a more difficult recovery to put the stick forward and use the rudder because of my tendency to overcontrol in sideslip and, after a cycle or two of chasing it, it diverges. So I'd go down to a 9 on that.

ML — CONFIGURATION 2

	$1/T_{\theta_2}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p-(g/U_o)$
i.c.	-0.259	0.957	0.244	—	—	1.0	1.28	0.17

RUN 2A

Configuration 2 and relaxing the back stick only. Can't track the target very well this time. As soon as it starts to go off directionally, if I continue to follow the ramp, then I get a departure and the departure seems to be coming right at pedal shaker. If I relax back stick the instant I can't follow the target directionally, I get a recovery. But I've got to do that right then. If I let it move at all it doesn't recover. The major deficiency is that it departs so quickly with so little target movement. Controllability is not a question and just relaxing the back stick recovers it. I have to come up with a 7 for that condition.

RUN 2B

If I release the back stick and chase it with aileron I get a recovery, but I do much better if I leave the aileron out. I tend to cause sideslip divergence by trying to bring the bank angle back to zero with aileron. That's an 8. If I'm allowed to push forward with the stick and use aileron I get a recovery and I'm able to damp the bank angle and sideslip out faster and it goes back to a 7. But this is a bad condition because it departs so soon. If you compare this to Configurations 4 and 1 I don't see how you could ever get a very high rating on it because of the problem of detecting the departure. Just can't track it very long.

RUN 2C

If I relax the back stick and attempt to recover with the rudder I can do it most of the time but it takes an awful lot of concentration to damp it out with the rudder, to decrease the sideslip. It's a 9. If I'm allowed to push the stick forward aggressively I can almost always recover, and it's improved over the case where I just relaxed the back stick. I'd go to an 8 on it. I wouldn't go to a 7 because one case there I did lose control.

RUN 2D

If I relax the back stick and chase it with aileron and rudder it's a pretty easy task. Considering the bad detection and the ease of recovering that way, I would rate it a 6. It's got an objectionable deficiency in that it departs quickly, but if you just relax back stick and use rudder and aileron you can recover it pretty easy. And if you're allowed to be more aggressive, then relax the back stick and push forward, you can even do better than that. I'd go to a 5, the reason being that I can go a little further in tracking and still get a recovery. Again, the big hammer seems to be relaxing the back stick.

RUN 2E

Now the warning's different for this condition; it's different than A, B, C, and D in that I can apparently track it to a better degree. But, when it goes and I simply relax back stick, it's gone so far that I can't recover it. That's a 10. Now if I'm allowed to push the stick forward aggressively, I track for a longer time. I finally see the departure; it's going just as fast as before, but I push the stick forward and I recover. I still have pretty high workload in keeping the sideslip down to zero with the rudder. Controllability is not in question. Recoveries were so consistent that it'd be a 7. It's quite a jump from just relaxing back stick to pushing forward. But I feel confident that I can recover almost 100 per cent of the time doing that. I can go way out and recover. I'm able to recover most of those with the target still in sight, until the nose gets too low, then it's out of sight. So being able to put the stick forward where I want it and go after it aggressively with the rudder made it pretty nice compared to just letting the stick go forward.

ML — CONFIGURATION 3

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	−0.216	—	—	0.461	0.064	0.71	1.58	0.17

RUN 3A

Recovering with forward stick you have a little more roll in the departure. One of the big clues is that you can't match bank angle with the target any more. As you increase angle of attack, you see a roll, a change in bank angle, and as you attempt to correct that to match the bank angle of the target you realize that you have lost control and you have to effect a recovery. You can't track the target very long. I'd say the inability to match bank angle is a good clue for detecting the departure; and if you relax back stick right at that time it'll recover, but it results in a lot of bank angle and nose drop. For the task of detecting and recovering from a departure I'd have to say there wouldn't be much improvement that I'd want. It lets me know, and if I relax the back stick I get a recovery. I'd give it a 3, because it's so easy to do and it really doesn't go that far.

RUN 3B

OK, we'll look at freezing the back stick and trying to stop it with aileron. OK. If you freeze the back stick and try to stop it with aileron you can't recover. And that's a 10. If you relax the back stick to trim and try to recover it with aileron, it's possible to cause it to diverge. In fact, you do that quite a bit I think. I'd rate it an 8 because you have a tendency to lose control without using a lot of attention. If I'm allowed to go forward with the stick and aggressively pursue the thing with aileron or aggressively go forward with the stick and pursue with aileron, I don't tend to lose control but it takes a lot of attention to bring the bank angle and β to zero. And I'd rate it a 7.

RUN 3C

If you relax back stick to trim and then recover with rudder, you can usually control it but it takes just about complete concentration on damping out the sideslip and bank angle. It's a 9. If you push the stick aggressively it improves a good bit; controllability is no longer a question, but it takes a lot of walking on the rudders. High workload. A lot of attention. It's a 7. In the recovery I'm trying to get the bank angle, looking at the horizon. Later, I look at the ball but it is going out of my view a good bit of the time, so it's no help. The only cue I have when the target disappears is bank angle.

RUN 3D

Relaxing back stick pressure and recovering with aileron and rudder is a 7. Pushing the stick forward of trim and recovering with aileron and rudder is a 6. In all these cases where I use aileron and rudder I'm just making the situation worse; I'm aggravating it by my control input.

RUN 3E

First of all, I can track better. I can track for a longer time. If I hold the stick aft and try to recover with just the rudder, I still can't do it. That's a 10. If I allow the stick to go forward I can recover, in general. But, it takes a lot of concentration. I'd rate it an 8 where I just relax the stick and recover with rudder. If I push the stick forward and recover with rudder it's much better than that. I'd rate it a 5. I can track a little longer and I have more confidence. Even though I see it starting to go I can hesitate a little bit, then push forward with the stick, use the rudder, and be sure of recovery. I'd put that down as a 5.

ML — CONFIGURATION 4

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta dyn}$	$N_p - (g/U_o)$
i.c.	0.015	0.982	0.235	—	—	0.944	1.28	0.17

RUN 4A

OK, again the indication that you're going to depart is the loss of ability to track directionally. You don't lose the ability to track in pitch but in yaw. Rudder is pretty effective at chasing the target directionally, and I don't get a lot of rolling from the rudder. The cue that I'm going to depart comes on with a reasonable rate so that I have pretty good warning that my nose is slicing, and I'm simply relaxing the back pressure and getting easy recoveries. Based on the assumption that I've got to have an airplane that departs, I'd have to say it's a 3 because it's easy to tell when it's going to depart, and just relaxing the back stick makes it easy to recover.

RUN 4B

The recovery relaxing back stick and using aileron is less satisfactory than simply relaxing back stick because you have a tendency to overcontrol again and drive the sideslip with the aileron. But it can be done. And we'll say that it requires considerable compensation, paying attention that you don't actually overcontrol to the point that you aggravate it and make it depart. I'd put that as a 5. That's simply relaxing back stick and chasing it with the aileron. If you push the stick forward and chase it with aileron, I'd rate it a 6 because you get a lot more response. You start getting some pretty rapid rolling out of the airplane and a tendency to acquire more gain and a higher pilot workload.

RUN 4C

If you relax the back stick and try to recover it with the rudder, sometimes you can and sometimes you can't. It takes intense concentration to try to zero the sideslip again because you tend to overcontrol and make the sideslip diverge even though the angle of attack goes down. That's a 9. Pushing forward on the stick past neutral is the same.

RUN 4D

If you relax the back stick and then use aileron and rudder, you have a tendency to continue to force the sideslip to diverge. You have to start the recovery earlier if you're going to control the airplane within close tolerance, let us say, keep the target in sight. If you start the recovery at the same time that you would if you just released back stick to get the recovery, then you tend to get about 50 per cent of them where you can't recover. It's a 9. If you push the stick forward and then use the aileron and rudder to [illegible] out the bank and sideslip oscillations, it is better than just relaxing the back stick. For some reason you seem to get more response out of the airplane and so don't have the tendency to diverge. You can almost always control it. And it's an 8.

RUN 4E

It doesn't seem consistent to me. I don't know what, maybe I'm getting punchy or something. There were times when I felt like I could fly it a lot farther. And when I went that far it was more difficult to recover because I'd gone so far, I guess. If I recovered where I had throughout 4, then it was a pretty easy recovery using forward stick and rudder. I'd give it a 6. I guess the objectionable thing about it is that when you push forward on some of those recoveries you tend to get quite high angle of bank, say 9 deg, then you get kind of lost in just where to go. But it's certainly controllable.

ML — CONFIGURATION 5

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta dyn}$	$N_p-(g/U_o)$
i.c.	0.015	0.978	0.231	—	—	0.534	1.77	0.17

RUN 5A

OK, that's the best I've seen. For detection, I start getting not what you'd call uncommanded wing rock, but I start getting some bank angle oscillations that I'm in the loop with and have difficulties tracking the target and so I'll finally give up. I can stay in with the shaker a long time and then I can give in when I can't get my nose to the target; just relax the back stick and it recovers. It's got to be another 3. I don't know what more you could ask for; it just tells you that you're in trouble and then when, after stepping a little farther out of bounds, you finally decide to give up, there's recovery. Not bad at all. As I oscillate back and forth in bank angle, I end up with the target sliding away and then I lower my nose a little to get back down to it. I could see that I was lowering my angle of attack while I was doing the tracking task. There was one time when the nose started sliding off and it was high, about 23 to 23-1/2 deg angle of attack, and then I tried to get the nose back and it got down to about 21.6, 21.7. If I had continued up in angle of attack at that point, even relaxing would have given a departure. Now the way I was getting my airplane back down to the target was with a lot of right rudder in most cases. I had 1/2 to 3/4 right rudder in, pulling the nose back down to the target. But I've got what feels a lot like an airplane. You know, you can do that in an airplane so you're wanting to get back down there and just stuff the rudder in and go back down. It feels a lot like an airplane.

RUN 5B

This is so much like an airplane that I have a tendency to continue to track till I'm completely gone, you know. It's hard to decide when to give up. This is very realistic to what you do in an airplane like this. If I go to that point, there's no way I'm going to hold the back stick and recover with aileron so I'll just give you a 10 right there. OK. I've come to feel my warning is when I can't track any more. I don't give up until I can't track any more. And when I wait that long it's too late to recover with just aileron and relax the back stick; it comes out a 10. Now if I mechanically quit it earlier than that I can recover it, I think, but I'm not recovering on the shaker. So if I'm not going to do that, then the first indication I get that I'm going to give up is when I can't track; and I'm going to drive it into departure, because I fly in much better than in the other conditions. Let's see if pushing forward will recover. Now I'm tracking and retracking, finally having to give up and push the stick forward, and doing some quick aileron movements to recover. I'd rate it a 4.

RUN 5C

What happens here is I'll go ahead and track and say, "Oh, I'm done, can't track any more." I try to take the ailerons out and just use rudder and it goes faster because the ailerons ar. helping so much. So when I give up at that point, the rudder's not going to do it. If I track till I have to give up, then just push the stick forward and push in, say, full rudder, it arrests the nose slice. It does it; it recovers. It does roll, and I know that in an airplane you'd be upside down in the straps; you'd be pulling negative g's through that roll but it recovers. And it recovered every time I did that. You know, on a lot of these other recoveries we pushed forward just a little bit and we pushed in a little rudder and got a recovery. In this case, it's taken full throw on both controls but it's doing it. It's not too hard to do in a simulator; I'm not sure you can do it in an airplane. Because the way we're normally strapped in, say in an A-7, you'd be lucky to be able to maintain that much rudder and forward stick at those negative g's. You're just not strapped in for that kind of flying. I'd rate that a 9 just giving it those considerations. Very unnatural thing to do.

RUN 5D

OK. Holding the stick back is a 10, and relaxing to neutral is a 10 also. The reason for that is you tend to go too long because of the situation you think you're still hacking the program after the target. Pushing the stick forward is a 9 and the reason is that usually you can recover but the added rudder and aileron inputs make it difficult to maintain control.

RUN 5E

It's a different track task because of the change; it makes it easy to recover. I'd put it about a 4. And the difficulty is controlling the bank excursions during the recovery with the rudder once the nose is down. For pushing the stick forward I'd go down to a 6 and that's because of the bank angle excursions which you have to damp out. You kind of lose the clue with that blank black screen, so you should keep that in mind. I don't know if I was going any further but it was an easier tracking task. I think if you compare the error on that with the other ones on this condition you will find I just rode a litt.e circle around the target. Relatively easy to do it, and you're still tending to drive yoursel?' right into the departure.

ML — CONFIGURATION 6

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	—	—	0.309	0.222	0.628	0.56	0.17

RUN 6A

If you really are concentrating on the tracking task the departure warning is not very good in this case I don't think. I get the impression that I'm going to be able to really track it and then all of a sudden, when I decide I can't any more, it's way too late. As I release the back stick, it continues to depart. I had to kind of mechanically come to the conclusion that the second I couldn't track it I had to release the back stick. When I did that it recovered. So for the whole task of detecting and recovering, it has bad warning for me. I tend to think I can do a better job and once I finally give up it's way too late. So I have to start recovery with very small excursion in the tracking task. Having learned that, I'd say it's controllable and it's easy to recover, but it takes mechanical compensation to know when to recover. I'd rate it as an 8.

RUN 6B

OK. We'll try to recover with aileron, freezing the back stick. OK, now that I can use aileron more I don't have to recover as fast, because I can bank back towards the target or away from the nose slice and, if I do that with the stick back, it won't recover. The angle of attack continues to go up. That's a 10. But if I relax the stick and bank back towards the target or away from the nose slice, then it's fairly easy to recover. And I would put it about a 5. If I'm allowed to push the stick forward I can allow the departure to go a little further. But, using the same detection point and banking into the target or away from the slice and pushing the stick forward, I end up with a higher workload because of the rapid bank excursion. It's a little harder to recover, takes more concentration. I'd go down to a 6 with that.

RUN 6C

If I simply relax the back pressure and use rudder, I could control it enough of the time to give it a 9. But it's very difficult to damp the sideslip and the bank angle excursion. If I push forward on the stick as I attempt to recover with the rudder, I can do it well, and it's about a 6. This takes a lot of concentration on the rudder but I can do it quickly.

RUN 6D

(Commentary lost due to tape overrun.)

RUN 6E

I can't track any better on this. If I try to use the rudder I make it depart. If I just use the rudder below shaker then it tends to depart. So I feel that it's uncontrollable. If I raise the angle of attack, follow the ramp, allow a nose slice to start, and freeze the back stick, I can't recover. That's a 10. If I follow the ramp and simply let go at the slice, it'll recover. But, without even following the ramp, and just allowing some sideslip to build up, it takes all I can do to keep it from departing even at 18.9 deg. So I'd rate it as a 9 because I can sit there but I can't really follow the ramp. In other words, if you took the ramp out and just asked me to follow the target back and forth at this angle of attack, I think I could probably keep from losing control, but that's all I could do. Terrible airplane.

ML — CONFIGURATION 7

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	0.015	—	—	0.309	0.222	0.628	0.56	0.17

RUN 7A

Departs so rapidly once there's a movement one way or the other directionally that you have to recover immediately. You can't try to retrack the target; it's impossible. If you allow the target to move a little bit and then try to retrack it, that'll cause a bad enough departure that you won't recover by releasing the back stick. So just releasing the back stick it's a 9. By pushing forward I can go a little further; I can retrack the target once. I can realize it's departing and still play with the target a little bit, and then aggressively push the stick forward and it'll recover. Controllability is not in question. The small amount of tracking I can do is bad plus the motions after I push the stick forward and kind of objectionable too. It does recover. I'll go to a 7 for that. The warning is less than usual but it's good because you can't do the tracking task.

RUN 7B

If I simply relax back stick at the time to recover for this condition, and use aileron, I can recover the aircraft quite handily simply by banking into the target or away from the nose slice. And I'd rate that a 4 because of the ease of doing it. Now when I push forward I get more rapid bank excursion, and I'd rate it a 5 because of the difficulty in controlling it.

RUN 7C

If I release the back stick and put the rudder in, it won't recover. I make it diverge in sideslip. If I just go to operate and start some sideslip in, it'll depart. If I push the stick forward it'll recover. Relaxing the stick and using rudder is a 10. Pushing the stick forward and using rudder is an 8 because pushing the stick forward gives me enough control over the airplane that I can use the rudder. The only way to fly it is not to use the rudder. But I can do it if I push the stick forward, and it's a little better than a 9 at that time — about an 8. For recovery I have to use the horizon. The target is a good reference while it's in front of me but after that's gone then all I've got is the bank angle. So I'm trying to damp out bank angle and in so doing I get large excursions in β.

RUN 7D

If I relax the back pressure, the ability to roll helps me to recover. But then I have to take quite a while to keep from letting the sideslip diverge, and I mostly bring that back in by banking. Banking away from the nose slice damps out the sideslip for me. Using the rudder is fine but it's just faking me out. The thing that's doing it is banking. I would put relaxing the back stick at an 8. If I push forward on the stick, I'd put it a 7 because I can damp it faster. I don't have so many excursions.

RUN 7E

OK, nose slice is to the right and I'm banking to the left; if I can point it towards the horizon I can recover. I saw 20 deg of sideslip and still, by banking towards the horizon, I could recover it. Since I don't get a motion cue and my nose is going, I control towards the target until it disappears or bank towards the horizon. But rudder just doesn't get me around there in time. If I could make a rudder bank away from the nose slice, I'd be able to recover, but I can't get it around there. OK, if I hold the stick back it won't recover, and that's a 10. If I relax the stick and try recovery, I lose it, and that's a 10. If I push the stick forward I can recover pretty well. It's a 7.

ML — CONFIGURATION 8

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p - (g/U_o)$
i.c.	−0.033	−0.583	0.304	—	—	—	0	0.17

RUN 8A

OK, I'd say that's the least warning we've seen. Configuration 7 would rank next to it, but this is worse. As soon as there's any movement of the target in yaw, any directional movement of it at all, I've had it. I can chase the target for a while with the rudder but I'm really already gone. As soon as it moves I've got to start a recovery. Just releasing the back stick won't recover it. Maybe it'll recover if I push it forward. Control's not a question there, but I've got to watch the target and start a recovery as soon as it diverges. So it's a 7.

RUN 8B

I think relaxing the stick and using aileron is a 10. That's just because usually you're going to lose control. Again, it has a little bit to do with the mechanization of what we're doing. I don't get a clue about my sideslip when that ball's gone, see. And as you saw, I could bring the wings level and still it would go in yaw. Now if I push forward on the stick I can get to wings level and I can also bring the ball back into view, and then just by tracking the ball I can maintain control. And that's a 9. Not a very flyable situation.

RUN 8C

Relaxing stick and using rudder is a 10. And pushing stick and using rudder is a 7 because we're out of the area where controllability is a question, but still I've got to make sure I keep the ball in the center. If I let the ball get out, it's going to go. You know, that's quite a quantum jump to go all the way from 10 to 7. But I just don't feel it's that much work as far as maintaining control. I can even go a little further, you know. The thing that's doing it is pushing the stick forward. The less I do with the rudder, or as I decrease my rudder inputs, the better it flies — get the old pilot out of the loop. OK, rudder and aileron.

RUN 8D

Relaxing the stick to neutral is a 10. That was kind of insidious because it looked like I'd have it, you know. I wouldn't have any clue, and then all of a sudden, zow, it'd go. It got so that I looked a couple of times and watched the sideslip build up and it was really building. Just looking at the screen you don't see it. Neither the ball nor the bank angle tell you. Pushing the stick forward aggressively can recover you and I can do it consistently, but it's an 8 because of the bank angle excursions, rapid banking.

RUN 8E

Relaxing the stick does not recover because it diverges. Pushing forward on the stick is kind of insidious. You have to add two things together on this one. As is kind of typical of this, I can track better. I can reacquire the target and recover, by pushing the stick forward, better than I could on any other conditions on this configuration. But it tends to go a little further this time and if I did that I often lost control. So detection, under this condition, if I separate it from the rest of Configuration 8, is not so good because I'll sit there and be tracking the target and then really lose control. If I go back and recover just like I was under the other A, B, C, and D, at about the same point, then it's not such a bad problem except that damping the bank angle is a big task. So combination of those two I would not go above a 9 for that. I'd figure it was a 10/10/9.

ML — CONFIGURATION 9

	$1/T_{\theta_3}$	ζ_{SR}	ω_{SR}	$1/T_R$	$1/T_s$	ω_φ/ω_d	$N_{\beta_{dyn}}$	$N_p-(g/U_o)$
i.c.	-0.071	—	—	0.53	0.03	0.675	1.68	-0.064

RUN 9A

I'm going to have to call that a 10, and the problem is detection. The nose slice isn't apparent enough to indicate that you've lost it. If you try to retrack it you're done. It turns out that you could mechanically set a rule that you'd cease tracking with any movement away from tracking. You haven't yet departed; and if you let go of it then, it doesn't depart. But if I make any attempt to follow it and then say, "OK, now recover," it departs. It will initially go where I want but then it'll depart. The rule would have to be, just don't follow the target, don't track it. If I don't try to track it then it doesn't depart. That's a 6. The minute it starts to the left, I say "unck" and let go. Why, I didn't even get to pedal shaker, and it started to the left. I had to let go because I know that once it starts, if I go after it at all, and even though it doesn't depart at that instant, I've gone too far. That time I did let go about the time the pedal shaker came on and it didn't recover.

RUN 9B

This looks like it has a little wing rock, you know, uncommanded. One thing I've been doing a little more today than before, I'm saying, "OK, I let go," and then go inside on the 8 ball. Since I'm pushing horizon out of sight and I don't have any other clue, I can come inside and look at the 8 ball and recover. So, holding the stick back is a 10. Relaxing the stick is a 9 because I can just maintain control by real concentration. I can recover pretty handily pushing the stick forward if I transfer my attention inside, but still have a high pilot workload. And I'd go to an 8 on that. Control is still a problem. I can go a little further. I can't reacquire the target but I can spend a little more time. I can actually let it diverge just a little bit and then push the stick forward.

RUN 9C

Sometimes I put the wrong rudder in and make it go, I don't know why I do that. You can hang in there a lot longer but it still eventually goes. OK, pull the stick back, it's a 10; you can't recover it. Relax the stick it's a 9 because you can recover, but it's hard to maintain control. You tend to diverge in rudder. It's an 8 if you push the stick forward; you can recover it faster but it's still high workload. It wouldn't be hard to lose control.

RUN 9D

OK. If you hold the stick back, it won't recover. It's a 10. If you relax the back pressure, it's an 8. You tend to lose control again after you once stop it. Got all the rolling and yawing going on. If you push forward on the stick it's a 7; controllability is not a question but it takes a high workload to damp those oscillations.

RUN 9E

I don't understand it. When we started this one didn't I say that if you follow it at all it would not recover? Why does a change in L_{δ_r} change that? The only thing I can see that would change is the amount of sideslip that you have at the instant you give up and decide to recover. I can track better, then let go and it recovers. I'm doing a lot more with it than I was at first. Gee, that's amazing. See, I told you a little while ago that if it got that far off I'd have to let go and recover it. OK. And then if it got any further off, when I let go to recover, it wouldn't recover. And now it's no problem. It's a tolerable workload if I just relax back pressure at departure and use rudder. That's a 6. If I push the stick forward it's a 5. I get a little more positive recovery. That's made a marked change in the ability to track. Had some real warning where I could tell "Yeah, I'm losing it," where before I had to be kind of mechanical about the rudder and forward stick.